BACKGROUND, GUIDELINES, AND RECOMMENDATIONS

FOR USE IN ASSESSING

EFFECTIVE MEANS OF CHANNELING

NEW TECHNOLOGIES

IN PROMISING DIRECTIONS

Prepared For The

National Commission on
Technology, Automation, and Economic Progress

by

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Foreword

During the Eighty-eighth Congress, several bills were introduced with the aim of establishing a Commission to study questions of technological progress, automation, the impact of technology on employment, and the potential application of technology to human and community needs.

In August, 1964, Public Law 88-444 was enacted, authorizing the establishment of a National Commission on Technology, Automation and Economic Progress.

Commission members were appointed in December, 1964, and have met frequently since. A Commission staff was appointed and studies of several questions were encouraged.

The four primary functions of the Commission, as spelled out in the legislation are:

(a) identify and assess the past effects and the current and prospective role and pace of technological change;

(b) identify and describe the impact of technological and economic change on production and employment, including new job requirements and the major types of worker displacement, both technological and economic, which are likely to occur during the next ten years; the specific industries, occupations, and geographic areas which are most likely to be involved; and the social and economic effects of these developments on the Nation's economy, manpower, communities, families, social structure, and human values;

(c) define those areas of unmet community and human needs toward which application of new technologies might most effectively be directed, encompassing an examination of technological developments that have occurred in recent years, including those resulting from the Federal Government's research and development programs;

(d) assess the most effective means for channeling new technologies into promising directions, including civilian industries where accelerated technological advancements will yield general benefits, and assess the proper relationship between governmental and private investment in the application of new technologies to large-scale human and community needs;

This study is directed toward aiding the Commission in its deliberations of the fourth of those points--assessing effective means of channeling new technologies in promising directions.

Purpose and Scope of This Paper

One task of the National Commission on Technology, Automation, and Economic Progress is to assess the most effective means of channeling new technologies in promising directions.

This paper is directed to that question. This paper does not recommend any single "most effective means." That ideal probably does not exist. Certainly, too little is known about the complex process of technology transfer to permit any such sweeping judgments at this time.

This paper then directs itself principally to the following questions: (1) Is the transfer of technology a worthwhile national goal? (2) Is there sufficient technology available, from federally supported sources, to permit a useful inter-sectoral transfer effort? (3) Is the available technology relevant to those needs and objectives that will aid the national interest? (4) Can technology be transferred from one industry to another, one discipline to another, one region to another, one mission-orientation to another mission-orientation? (5) What is known about the incentives and barriers to the transfer of technology? (6) What transfer mechanisms, or channels, have been employed to date? With what success? (7) What has been learned in transfer efforts to date that will aid in the development of future efforts of this type? (8) What has been the degree and type of involvement of the Federal Government in technology transfer to date? (9) What are the essential elements, as perceived today, in any effective method of channeling new technologies in promising directions?

To prepare this paper, the authors conducted depth interviews with personnel in the agencies that currently have significant technology transfer and technical information dissemination programs. A comprehensive literature search was also completed.

Conclusions and Recommendations

. Devising means of channeling new technologies in promising directions--and bringing about the utilization of new technology for significant purposes other than the immediate use for which it was developed--these have become activities ranking among the most intellectually challenging undertakings of our time. It is recommended that encouragement be given, by government agencies and private organizations alike, to talented people from the many disciplines who can contribute to the work, to bend their efforts to this cause.

. The transfer and utilization of new technology offer immense opportunity to the nation. There is widespread agreement among those who have studied the issue that the knowledge resulting from public investment in R&D constitutes a major, rapidly increasing, and insufficiently exploited national resource. The effective use of this resource can increase the rate of economic growth; create new employment opportunities; help to offset imbalances between regions and between industries; aid the international competitive position of U. S. industry; enhance our national prestige; improve the quality of life; and assist significantly in filling unmet human and community needs. It is recommended that more effective use of this technology resource become a national goal established at the highest levels.

. Measures exist to show that a considerable portion of the technology resulting from military/space/nuclear work is relevant to needs outside those mission areas. It is recommended that those who can bring about or influence the use of this technology in the civilian economy be alerted to the relevance of the technology.

. Traditional means of transferring technology--such as the inter-sectoral movement of knowledgeable people, corporate diversification, conventional library systems, the college classroom, and the technical journal--while still extremely important, are no longer wholly adequate. This is due, in part, to the sheer volume of new technology being generated, the rapid pace of its discovery, the increased complexity of the economy, and the technological gap between the military/space/nuclear sector and the main body of the economy. It is therefore recommended that complementary mechanisms be devised to aid in the channeling, transfer, and utilization of new technologies from sector to sector, industry to industry, region to region, discipline to discipline, market orientation to market orientation.

. It is increasingly apparent that a communications gulf exists, as a derivative of the technology gap, between the principal generators of new knowledge and large bodies of potential users. This is not a simple problem of language, but a complex problem involving attitudes, values, goals, work patterns, orientations, environments, and other variables. This results in a need for intermediaries or couplers who can operate effectively at the interface between knowledge and need, who can communicate effectively with those at both ends of the pipeline. It is recommended that professional societies, foundations, trade associations, and other groups aid in the definition and development of coupling mechanisms and the location and training of people who can perform the function.

. Technology transfer is one of the many areas in our economy where it is difficult to move programs forward because the responsibility is shared by the private and public sectors. The issue is complicated further by the fact that existing federal programs to perform the function vary in their level of government involvement by several orders of magnitude. It is recommended that a national policy be devised spelling out the conditions under which federal agencies should conduct, foster, or support programs at each of the various levels.

. The pressing nature of the problem tends to lead to proposed "solutions" of a sweeping, but impractical, nature. Several times, it has been proposed that a "national system" be created. Far too little, it seems obvious, is known at this time to design a single national system--and it is unlikely that this would be the optimum solution in any case. It is recommended that this question be given serious and continuing analysis, with an eye to the feasibility of designing a national capability made up of a multiplicity of coupled, user-oriented systems, with workable switching devices and the capability to tailor output for specific, but continually changing, groups with common needs or objectives.

. Significant benefits can result from the application of technology generated by one federal agency to the missions of other agencies. It is recommended that inter-agency efforts be encouraged and fostered, and where practical, that special skills residing in one agency be employed, on an ad hoc basis, by other agencies.

. Federal expenditures for scientific and technical information are large and increasing. In order to reap the maximum rewards from this investment, there should be as much commonality among systems, in their languages, abstracting and indexing approaches, and other points of interlock as can be achieved consistent with the overriding requirement for each to best serve its particular audience.

. The solution of pressing urban problems, from a technological viewpoint, and the enhancement of economic growth as a result of technological advance, both rest on the ability of private companies to innovate. So the focus for any broad-scale program to transfer technology must be the innovative technical community within private industry.

. Technical information is a marketable commodity. And true transfer programs add value to that information by abstracting, categorizing, separating out the significant, dividing the relevant from that which is not, and by interpretation, analysis, repackaging, and provision of local access. The user of a system should therefore be expected to share in the cost of its operation.

. Awesome opportunities for slippage exist at each stage in the processing of technical information. It is recommended that increased attention be devoted to the software aspects of mechanized systems and that special emphasis be given to education in abstracting, indexing, and the design of search strategies.

. There is no substitute for the effect that a "personel champion" of new technology can have. Research should be undertaken to determine the characteristics of such people and the means of locating them. Users of new technology should attempt to find such people within their organizations and place them in positions where they can work toward developing the maximum benefit for their organizations from the technology resource.

. New technology has no value until it is recognized. To glean the optimum knowledge from federal R&D programs, it is recommended that all agencies with significant R&D budgets establish a means of identifying the new technology they create, in-house and through contractors and grantees.

. New technology has no value until it is used. It cannot be adapted for use by an organization unaware of its existence. It is recommended that all those involved in programs to channel new technologies in promising directions spend some time on the marketing aspects of the business, communicating to prospective users the vast potential value of the knowledge resource and reacting to the needs of special groups of users by tailoring programs to fit their requirements.

Introduction

We find ourselves today between a forest and an ocean--a forest of new knowledge and an ocean of need.

This year, more than $15 billion in federal funds will be used to create new knowledge through research and development. We are generating more new knowledge in one year than we generated in a full decade less than half a life span ago.

In fact, if you will look upon the last 50,000 years of man's existence in terms of life spans, the speed of our progress--the pace of change--is readily apparent.

Because 800 life spans can bridge more than 50,000 years.

But of those 800 people...

...650 would have spent their lives in caves or worse.

...Only the last 70 had any truly effective means of communicating with one another.

...Only the last six ever saw a printed word or had any real means of measuring heat and cold.

...Only the last four could measure time with any precision.

...Only the last two used an electric motor.

...And the vast majority of the items that make up our material world were developed within the life span of the 800th person.

Such has been our progress but we've created equally awesome problems...

...We send men more than 160 miles above the earth's surface and return them safely, but we kill one another on our highways.

...We can create a comfortable living environment 300 feet below the surface of the ocean, but we breathe garbage-laden air in our cities.

...We can propel spacecraft at 18,000 miles per hour, but we move from home to work and back at speeds averaging only a little more than a horse trot. In fact, many of us waste the equivalent of a full month's working time each year simply getting to our workingplaces from our homes and back again.

...We can control nuclear reactions, but our ability to prevent crime is so meager that our sisters and daughters cannot safely walk on the streets of our cities after sundown.

...We can fabricate aerospace parts to tolerances of millionths and drill holes smaller than human hair, but we can't seem to make parts of childrens' toys fit together.

Or can we do all of those things? And many, many more?

How much of our available knowledge is really being used for all those purposes for which it is relevant?

How can the scientist, engineer, or businessman with a problem or a need for new knowledge find out what is known about solving his problem or meeting his objective?

How much of the new technology developed each year with public funds can be applied to public needs in the civilian sector of the economy?

How much of this new technology can be translated into improved products and processes to spur economic growth and improve our standard of living?

No answers can be given to such quantitative questions. But this study shows that there is much to be gained--in both the quantity and quality of life--from better exploitation of available knowledge.

Technology As A Factor in Economic Growth

While this paper is concerned with means of making new technology available to those who can use it, it seems important first to determine whether the candle is worth the race. Will the benefits employing new technology warrant an investment in the means of making it available?

All indications are that it will.

Only recently[1] have economists devoted much attention to casual relationships in economic growth. But throughout the literature, one can trace the awareness--by economists and policy makers--of the importance of science and technology in economic health.

More recently, economists have attempted to measure the contribution of technology to the rate and volume of economic growth.

R. Solow has estimated that, of the total increase in U. S. output per man hour from 1909 to 1949, only 1/8 was due to the increase in capital investment while 7/8 was due to technological progress.[2]

Solomon Fabricant has found that, during the 1871-1951 period, technological advance accounted for 90 per cent of the rise in output per man hour (vs. 10 per cent for capital formation).[3]

1. Despite Schumpeter's major contributions in this area in 1911, it is generally agreed that attempts to integrate economic growth into the mainstream of economic thought were not intensive until the last 25 years. Increased attention to the subject has been given in the last decade.

2. R. Solow, "Technical Change and the Aggregate Production Function," The Review of Economics and Statistics, Vol. 39 (August, 1957), pp 312-320.

3. S. Fabricant, "Resources and Output Trends in the U. S. Since 1870," American Economic Review, Vol. 46 (May, 1956).

Benton Mossell, in a third study, found that (during the 1919-1955 period) technological changes accounted for approximately 90 per cent of the rise in output per man hour.[4]

Edwin Mansfield, in a study of innovation and its effect on the growth of individual companies, found that the innovative companies grew much more rapidly (during a five-to-ten-year period after the innovation occurred) than other firms in their industries. The average growth rate of the innovators was often twice that of the others. The average effect of a successful major innovation was to raise a firm's annual growth rate by 4 to 13 percentage points.[5]

George Kistiakowsky has concluded that: "As to the recent past, we have overwhelming evidence that scientific research translated into technological innovations through the media of organized applied research and engineering development, has had a dominant and beneficial effect on the welfare of advanced nations, thus adding health, military, and economic value to its intrinsic cultural value.[6]

4. B. F. Mossell, "Capital Formation & Technological Change in U. S. Manufacturing," <u>The Review of Economics and Statistics</u>, Vol. 42 (May, 1960) pp 182-88.

5. <u>Reviews of Data on Research and Development</u>, Number 38, (National Science Foundation, Washington, D. C., March, 1963). See also: Mansfield, Edwin, "The expenditures of the Firm on Research and Development," Cowles Foundation Discussion Paper No. 136 (Yale University, 1962).

6. <u>Basic Research and National Goals</u>, A Report by the National Academy of Sciences to the Committee on Science and Astronautics, March, 1965, page 169.

Zvi Griliches asserts that "it is clear by almost any conventional method of measurement that productivity increase has been the most important component of economic growth in the United States in recent decades. The growth in productivity in turn can be divided into two parts: (1) the improvement in efficiency due to the elimination of various disequilibria, and (2) the expansion of the boundaries of knowledge."[7]

Edward Denison predicts that advances in knowledge will be the most significant stimulus for economic growth during the 1960-1980 period.[8]

It is apparent to even the most casual observer that advancing technology has drastically transformed the character of man's activity. A century ago, men and animals provided nearly all the musclepower in industry. Machines supplied about 1 horsepower per production worker. Machines now provide more than ten times that amount of energy. The farm population, in that time period, has decreased from 8 in 10 to less than 1 in 10, thanks to increased farm mechanization. And since 1860, the average life span has jumped from around 40 to around 70 years, owing to medical advances in the prevention and cure of disease--and to gains in sanitation and nutrition.

It is clear that the infusion of new technology can speed the rate of economic advance.

But the importance of new technology to society cannot be measured solely by its contribution to our Gross National Product. GNP measures, with limitations, the output of goods and services in the national economic system. But any realistic assessment of economic performance must also consider how that output is distributed, the

7. <u>The Rate and Direction of Inventive Activity: Economic and Social Factors</u>, Report of the National Bureau of Economic Research (Princeton University Press, 1962).

8. Denison, Edward, <u>The Sources of Economic Growth in the United States and the Alternatives Before Us</u>, Supplementary Paper No. 13 (New York: Committee for Economic Development, 1962).

ability of the system to make the generation of that output personally rewarding, and the environment--or the quality of life--created by the system. GNP does not measure the economic system's performance in terms of giving people what they really want.

Much of the benefit of the infusion of new technology into the economy is not reflected in measures of productivity. For example, if technology permits the making of a better product, without a corresponding change in production costs, the result is not reflected in statistics of output--but is a decidedly beneficial action. Likewise, if new technology helps to enlarge the number of choices open to a consumer--as it does--not all of that benefit is reflected in our measures of economic output. Our measure is the sum of products not available in a prior year valued in terms of the products that the resources used in production could have provided in the later year if used to make the products that did exist in the earlier year.[9]

Richard R. Nelson has put it this way:[10] "The conventional measures used by economists as indexes of increased economic performance do not adequately take into account the contributions to improvement in human life made by many kinds of technological advance. There are a number of conceptual and practical difficulties with the GNP measure--the problem of defining "final goods," and thus deciding what should be included and what should not, the problem of taking proper account of changing quality, and the fundamental and unsolvable problem of devising an appropriate rating system so that the rate of growth of GNP means something sensible and interesting when the different goods and services which comprise it are growing at different rates. (Or what is in principle the same problem - developing a meaningful GNP price deflator.)"

9. This line of reasoning is more fully developed by Denison in The Sources of Economic Growth in the United States and the Alternatives Before Us, Supplementary Paper No. 13 (New York: Committee for Economic Development, 1962), pp 155-162.

10. Nelson, Richard R., "The Effect of Research and Development on the Economy," Rand Corporation Monograph, September, 1963.

He continues: "Consider the contribution to economic capability made by the invention and development of processes for catalytic cracking of hydrocarbons. From the point of view both of final consumers and of the GNP accounts, catalytic cracking does not permit the production of anything really new. What it does is to permit an increase in the amount of motor gasoline and other high value products which can be obtained from a given quantity of crude petroleum. More important, considering the human and material resources used at all stages in the production process from drilling for oil to producing the gasoline, catalytic cracking permits an increased amount of gasoline to be produced to given quantity of human and material sources. In other words, catalytic cracking increases productivity. Assuming (to simplify the discussion) that there is no change in total resources used in the production of gasoline, the value of this increased output permitted by catalytic cracking will be counted as an increase in GNP. And in this case this measure seems a quite reasonable first approximation to the contribution to the ability of the economy to produce wanted goods and services made by the invention and development of catalytic cracking. But consider the invention and development of the airplane. Unlike catalytic cracking, the invention of the airplane permitted the economy to provide a service which could not be provided before. If there were no airplanes, it simply would be impossible to go from New York to San Francisco in less than two days, much less five hours. Not just more costly (in terms of resources and manpower required) or more convenient--but impossible! How much do we value this possibility? Certainly by much more than the dollar amount of air travel fares, yet this is what GNP (as we presently calculate it) counts.

"Sometimes (as with catalytic cracking) technological change simply increases the quantity of existing goods and services the economy can produce. But sometimes (as with the airplane) technological advance permits needs to be met better than they were met before, or even permits the satisfying of needs which could not be met at all before. This broadening of the possibilities of human life is hardly touched by the GNP calculations.

"Even using the GNP measure, it appears that technological change has played a major role in contributing to the improved ability of the economy to meet needs. Among the factors that contribute to the productive potential of an economy are: (1) the size of the available labor force and the number of hours they wish to work, (2) their education, health, occupational skills and experience, incentives, and motivations, (3) the stock and age of plant and equipment, (4) the state of development of the infrastructure - roads, water systems, school buildings, etc., (5) the terms on which the economy has access to natural resources, (6) the state of technological knowledge which defines what can be done with labor, capital, and other resources. The growth of economic potential is determined by the rate at which these basic determinants are increased or improved. Combining these results (and ignoring certain interactions), the effect of increases and labor, capital, and average educational attainments taken together falls significantly short of explaining fully the increased GNP we have experienced.

"Technological change undoubtedly has been a very important factor contributing to the change in the composition of output and employment we have experienced since 1900 in the United States.

Mr. Nelson concludes: "In summary, the major effect of research and development on the economy is to increase our capability to meet needs and aspirations which can be satisfied by goods and services. There is no question that technological change is disruptive, and this fact should be borne in mind and better policies developed to deal with the problem. But there is no evidence that research and development, directly or indirectly, lies at the roots of our recent problems with high overall unemployment rates, nor is there any reason why, with sensible policies, we cannot utilize fully all the increased potential for meeting needs that research and development can yield us."

One approach to the full realization of that increased potential, it appears, would be to arrange for the beneficial effects of new technology to be more widely felt--to be diffused into more industries, more governmental missions, and more regions of the country. In other words, programs to channel new technologies in useful and satisfying directions can have the effect of notably enhancing the rate of economic growth--though the full effect of such programs would likely not be measured by conventional methods.

John H. Rubel has suggested that five parameters be used to measure economic growth: Productivity, New Products (End Items), New Technologies and Devices, New Techniques (Scientific and Managerial), and New Industries.[11] He used the chart reproduced on the following page to illustrate his meaning.

All of the parameters he has suggested are potential beneficial results of effective programs to transfer technology. Federally aided programs, carried forth by such agencies as the Atomic Energy Commission and the National Aeronautics and Space Administration, have contributed to growth in all five ways suggested, as will be shown later in this paper.

Denison[12] has shown that differences in levels of formal education attainment create significant differences in productivity. It follows that differences in practical professional knowledge acquired after completion of formal education can have a similar effect. In other words, the scientist, engineer, or businessman who continued to accumulate new knowledge--via being somehow updated in the latest R&D results in his field--would be more productive than the one who was not. If that logical assumption were indeed proved true, then investment (public or private) in programs to identify, evaluate, and utilize new technology would pay significant dividends in productivity improvement at the level of the firm or end user of the technology.

11. In The Role and Effect of Technology In the Nation's Economy, Hearings before a Subcommittee of the Senate Select Committee on Small Business, May 20, 1963.

12. Denison, Op cit.

Chief Parameters Which Measure Industrial Growth	Examples of Each from Private and Public Sectors	Principal Impact of Government (Especially Defense) R&D Expenditures
Productivity	Introduction of Electrical Machinery; Automation; "Scientific" Factory Management	Accelerated Impact of Automation; Greatly Increased Cost of R&D
New Products (End Items)	TV; Pyroceram; Nuclear Submarines; Rocket Engines	Creates Many New, Highly Specialized "Products", but Few Having Direct Civilian Application
New Technologies and Devices	Transistors; Etched Circuitry; Masers; Infra-Red; Radar	Greatly Accelerated Rate of Development and Exploitation
New Techniques (Scientific and Managerial)	Systems Engineering; Operations Analysis	Some Techniques (Eg. Pert) Finding Wide Acceptance; Others (Eg. Systems Engineering) Not Yet Widely Used Outside the Military-Space Sector
New Industries	Data Processing; Electronics; Solid Propellants	Most New Industries Depend Heavily on Military-Space Support for Their Existence

Following Denison's reasoning, programs to channel new technologies in promising directions could also contribute to economic growth by encouraging new ventures and shortening the mean time to profitability in new ventures as well as reducing risk in proposed new ventures.

And technology transfer might result in increased rates of capital investment. Knowledge of the capabilities of a new process or a process improvement could encourage earlier investment, by more users, in such capability. And since technological obsolescence (rendering equipment obsolete because of more advanced equipment in use by a competitor, at home or abroad) is today a more significant factor in capital equipment purchase than is physical obsolescence (or wearing out of equipment), this factor could be significant.

Many studies of the contribution of technology to economic growth have concentrated on the economic impact of major inventions and innovations. But the most important contributions to economic growth may be stimulated by widespread adoption of incremental improvements.

John Jewkes[13] notes that: "There is no evidence which establishes definitely that technical or economic progress receives greater contributions from the few and rare large advances in knowledge than from the many and frequent smaller improvements. Economically, it might for a period well pay a community to starve its scientific and major technical work and to devote resources to the most thorough and systematic gathering together and exploitation of all the immediate and tiny practical improvements in ways of manufacture and design."

Dr. Charles Kimball asserts that "in many areas, the production of knowledge has outstripped its use."[14]

13. Jewkes, John, Sumers, David, and Stillman, Richard, The Sources of Invention (St. Martin's Press, New York, 1959).

14. Kimball, Charles, "The First NASA Regional Technology Utilization Program--A Three Year Report," Speech before the NASA-University Program Review Conference, Kansas City, Missouri, March 3, 1965.

He suggests this has resulted in "a growing mismatch, creating economic waste and social problems." He notes that "we have generated over $75 billion of potentially useful information in the U. S. in the past eight years," and asserts that "we are making inadequate use of it."

Dr. Kimball and others[15] see many serious economic and social implications in this situation. Among the difficulties mentioned as growing out of this problem are the following:

. Regional economic imbalances. With the three states of California, New York, and Massachusetts obtaining approximately half of total federal funds for performance of research and development, there is a tendency for industry in those regions to reach a level of technological sophistication far above that possible in such states as Arkansas, Georgia, Iowa, Oklahoma, and Kentucky which receive far less than the geometric mean distribution of R&D funds.

But if the technology resulting from R&D performed in California could readily be channeled into those industries in, say, Ohio and Iowa, where the technology were relevant, the chances for regional imbalances in technological capability would be lessened.

. Industry imbalances. The current pattern of R&D fund distribution could also tend to create serious inter-industry imbalances. For example, consider the machine tool industry. Its technological health is important to the national defense posture and to the ability of other industries to reach high levels of productivity. But nearly every significant new advance in metal cutting and metal forming has been developed by a firm not traditionally part of that industry.[16] It is argued that a better

15. Several views on this question are amplified in Government and Science, Report of the Daddario Subcommittee on Science, Research, and Development of the Committee on Science and Astronautics, U. S. House of Representatives, 1963.

16. Examples of such advances include electromagnetic forming, electrohydraulic forming, explosive forming, numerical positioning control, electrochemical machining, laser machining, and electron beam cutting.

means must be developed to channel the technical advances made in the aerospace and related industries to the machine tool industry and other basic industries,[17] where such technical advances can be commercialized and in turn contribute to the technical and economic health of still other industries.

. Time lag. Enlarging the use of new scientific and technical knowledge, it is argued, would contribute to economic growth by reducing the time lag between discovery of new knowledge and its economic exploitation.

. International competitive position. Early and effective utilization of new technology will logically have a beneficial effect on the U. S. balance of payments via increased exports of U. S. goods. This comes about in several ways: (1) Adoption of new processes, process improvements, and techniques can help to reduce manufacturing costs, thus aiding U. S. goods to be more price competitive in international markets. (2) Adoption of technical advances in the form of new products and product improvements can expand overseas markets for the output of U. S. factories. (3) Utilization of new technology can lead to the creation of entire new industries whose output can be sold worldwide. (This has, of course, been the case in such instances as commercial jet aircraft and computers.)

Perhaps none of the specific arguments in themselves make a conclusive case for the fact that channeling of new technologies in promising directions will significantly speed economic growth. But the arguments that have been

17. For this discussion, a basic industry is considered to be one whose products are widely used by other industries whose level of productivity advance is significantly influenced by the quality and cost of the products of the basic industry.

put forth by various students of the question--when examined in composite--make a formidable case for the theory.

Briefly, the individual arguments are:

. The use of new technology can reduce production costs, thus increasing productivity.

. The use of new technology can sometimes permit the output of a wider range of customer-satisfying products and services without a corresponding increase in capital investment, thus raising the return on invested capital--and/or permitting price reductions.

. The use of new technology can shorten the time lag generally experienced between the development of new knowledge and its widespread applications, thus spurring the growth process.

. The use of new technology can enhance the international competitive position of U. S. industry, thus improving our balance of trade.

. The use of new technology in the civilian sector--because such new technology will generally be adapted and coupled with other technology to create another sheath of new technology--can in turn provide new technological input to government programs in space and defense, thus enhancing our defense posture and aiding our international prestige.

. The use of new technology in some areas--medical research, urban design, mass transportation, to name a few--can improve the quality of life.

. The use of technology in one sector that was originated in another can help to provide a balance in the economy in terms of technological capability, thus avoiding problems that might--though would not necessarily--be created by the concentration of research and development effort in a relatively few companies within a few industries in a few geographical regions.

. The use of new technology can stimulate the production of new products, thus creating new jobs.

. The use of new technology can reduce the cost (thus, hopefully, the price) of producing existing products, thus freeing purchasing power for the acquisition of other products, creating additional jobs in those areas.

Is Technology Available for Transfer and Utilization?

It seems clear that more rapid and more widespread use of available new knowledge would tend to speed the national rate of economic growth, tend to smooth out regional and inter-industry imbalances, and enhance the U.S. position in international trade, thus having a beneficial effect on the U.S. balance of payments position.

But is new technology available for use? And--importantly --is the new technology relevant to the needs of society? This chapter is devoted to answering those questions.

Sources of New Technology

This paper places its emphasis on new technology developed as a result of federal programs, since only that portion of new technology is sufficiently in the public domain to be made available for widespread use via channeling and coupling mechanisms.

The Federal Government is currently supporting research and development programs at an annual rate of more than $15 billion. That is double the outlay in 1960, triple the amount expended in 1958, and 15 times the amount spent for the purpose in 1950 (see table on following page).

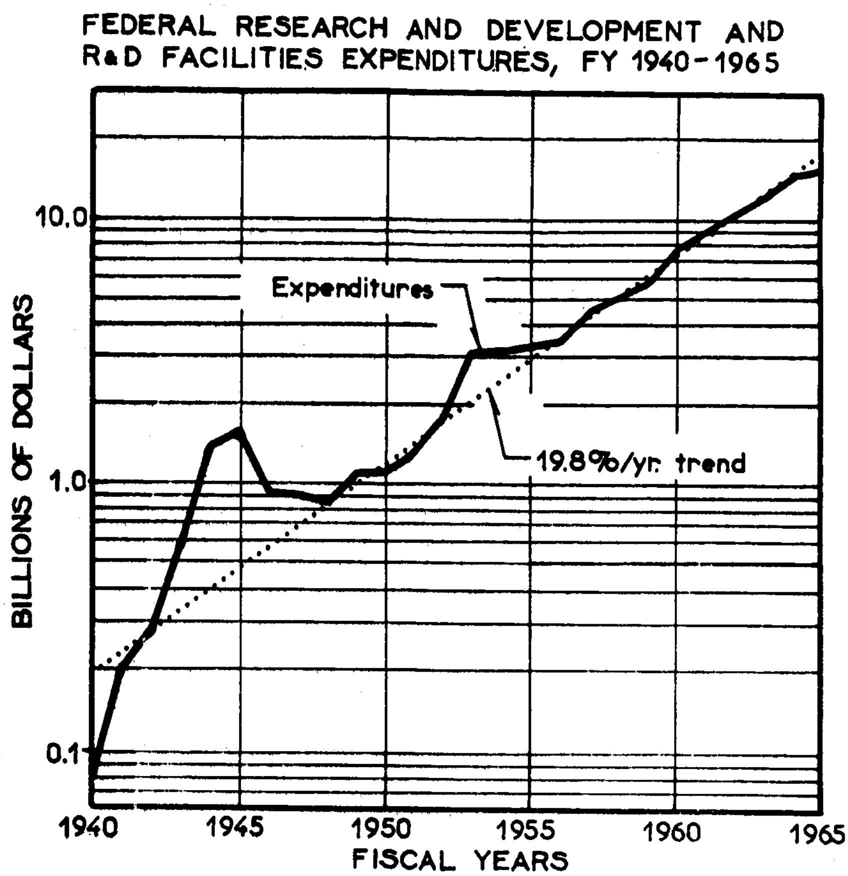
Since 1940, federal spending for research and development has risen at an average annual rate of nearly 20 per cent (see chart following).

Expenditures for Federal Research and Development, and Research and Development Facilities, Fiscal Years 1940-65

Fiscal Year	Total R&D and R&D Facilities (millions)[1]	Percent of Total Federal Expenditures[2]
1940	$ 74	0.8
1941	198	1.5
1942	280	.8
1943	602	.8
1944	1,377	1.4
1945	1,591	1.6
1946	918	1.5
1947	900	2.3
1948	855	2.6
1949	1,082	2.7
1950	1,083	2.7
1951	1,301	3.0
1952	1,816	2.8
1953	3,101	4.2
1954	3,148	4.7
1955	3,308	5.1
1956	3,446	5.2
1957	4,462	6.5
1958	4,990	7.0
1959	5,803	7.2
1960	7,738	10.1
1961	9,278	11.4
1962	10,373	11.8
1963	11,983	12.9
1964 (estimate)	14,883	15.1
1965 (estimate)	15,287	15.6

[1]Amounts for fiscal years 1940 through 1953 based on table XXXI NSF 63-11. Amounts for fiscal years 1954 through 1965 based on table H-1, pt.6, the Budget of the U.S. Government, fiscal year ending June 30, 1965.

[2]Calculations based on total federal expenditures listed in table 15, p.7, the Budget of the U.S. Government, fiscal year ending June 30, 1965.



Source: <u>Government and Science No. 2</u>, "Fiscal Trends in Federal Research and Development," Report of the Subcommittee on Science, Research, and Development of the House Committee on Science and Astronautics, 1964.

For every $100 spent by the Federal Government this year, approximately $15 will be spent for research and development. That compares with $10 in 1960, $5 in 1955, and $1 in the mid-1940's.

Federal spending for R&D is also increasing far more rapidly than total economic activity. Before World War II, federally supported R&D was equivalent to a few tenths of one per cent of the Gross National Product. By 1953, it equalled 1.4 per cent of the GNP and is now close to 3 per cent of the GNP.

Three agencies--Department of Defense, National Aeronautics and Space Administration, Atomic Energy Commission--account for nearly 90 per cent of federal R&D spending. The nature of the missions of these industries demands that these funds be spent across the full spectrum of R&D--from the most basic type of research to the most applied kind of development (which is really closely akin to plant engineering). The table below shows the sources of federal R&D funding by agency.

BUDGET EXPENDITURES FOR RESEARCH AND DEVELOPMENT, 1954-66
(in millions of dollars)

Fiscal Year	DOD[1]	NASA[2]	AEC	D/HEW	NSF	Other	Total
1954	2,487	90	383	63	4	121	3,148
1955	2,630	74	385	70	9	140	3,308
1956	2,639	71	474	86	15	161	3,446
1957	3,371	76	657	144	31	183	4,462
1958	3,664	89	804	180	33	220	4,990
1959	4,183	145	877	253	51	293	5,803
1960	5,654	401	986	324	58	315	7,738
1961	6,618	744	1,111	374	77	356	9,278
1962	6,812	1,251	1,284	512	105	409	10,373
1963	6,849	2,540	1,335	632	142	490	11,988
1964	7,516	4,171	1,503	791	197	496	14,674
1965	7,222	4,900	1,569	801	208	655	15,355
1966	6,880	5,100	1,557	936	266	706	15,445

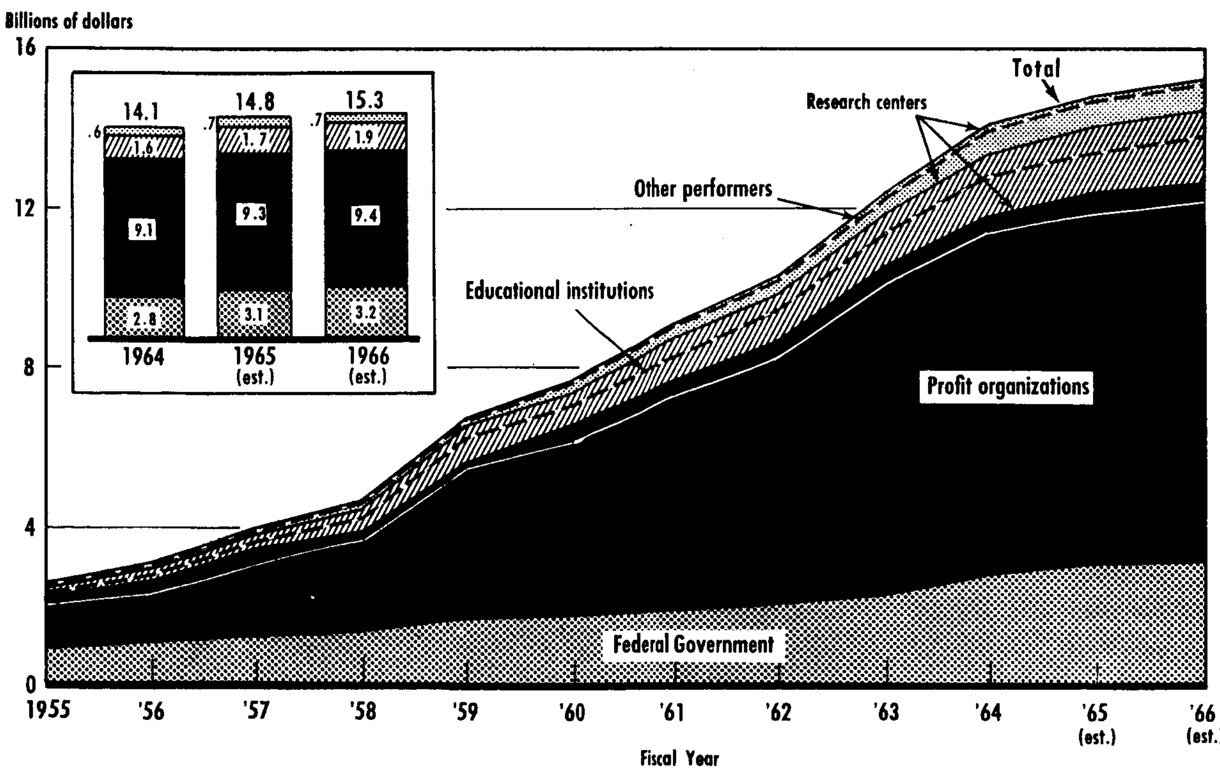
[1]Includes civil functions.
[2]National Advisory Committee for Aeronautics prior to 1958.

Source: National Science Foundation

In the last ten years, federal funds have paid for more than $88 billion worth of R&D--more than 60 per cent of it as a result of defense requirements. More recently, R&D in support of space exploration has risen to a place of importance nearly equal to that of the defense realm. And continued expansion of R&D by the Department of Health, Education and Welfare is bringing that agency into a funding position as important as the Atomic Energy Commission was in 1960.

Most R&D continues to be performed by private industry. Thus the bulk of new technology is generated within profit-making corporations (see chart). Thus any effective program aimed at channeling new technologies in promising directions--or any program aimed at finding secondary uses for the results of federally funded R&D--would have to incorporate some means of identifying and reporting new concepts, inventions, innovations, and other useful information generated within a diversity of corporate entities. The implications of this requirement will be discussed later in this paper.

Trends in Federal Obligations for Research and Development, by Performer



Source: National Science Foundation

There is no indication that federal funding for R&D has reached a peak; in fact, all signs point to continued growth of such outlays. While no rapid growth in federal spending for defense R&D is likely, continued expansion of federal support for R&D in such areas as space, health, nuclear energy, and socioeconomic areas seems likely.

Ralph Lapp[18] asserts that "it would be surprising" if federal expenditures for research and development amount to less than $35 billion annually by 1980.[19]

Mr. Lapp also predicts that the number of U.S. scientists and engineers with college degrees will rise to 4.5 million by 1980--or one scientist or engineer for every 22 people in the U.S. labor force.

By 1995, if present trends continue, there will be eight times as much scientific and technical information available as exists today.[20]

Numerous measures exist to show the volume of new technology being generated via U.S. Government programs. Among the measures are the following:

18. Lapp, Ralph, <u>The New Priesthood</u> (Harper & Row, New York, 1965).

19. He suggests the following divisions of that $35 billion: $10 billion for defense and arms control; $7 billion for basic research; $4 billion for bioengineering; $4 billion for continental engineering and land resource conservation; $3 billion for ocean engineering; $3 billion for space; $2 billion for atmospheric programs; $1 billion for a national data system; and $1 billion for all other purposes.

20. Hines, William, "A Scientific Data Moratorium?", Washington <u>Evening Star</u>, April 27, 1965.

• Around half the scientists and around one-third of the engineers in the U.S. are currently employed in research and development or its administration and management (the others teach, work in production, etc.).[21]

• More than 5 million scientific and technical articles are published annually in more than 100,000 journals, worldwide.[22]

• The U.S. currently accumulates more than 100,000 government reports each year, plus 450,000 articles and countless books and papers. On a worldwide basis, the literature is growing at the rate of an estimated 60 million pages per year.[23]

• There are about 225,000 "independent" and 235,000 "employee" patentees in the U.S.--equivalent to about 4 patentees per 1,000 persons aged 20 and over.[24]

• On December 31, 1962, the U.S. Government owned 13,671 patents and the number was increasing at the rate of about 1,900 annually.[25] A survey of scientists and engineers who made a group of randomly sampled, government owned inventions disclosed that around 10 per cent of the inventions assigned to the government also reached a stage of commercial utility.[26]

21. Rosenbloom, Richard S., "Technology Transfer--Process and Policy," National Planning Association Report No. 62, July 1965.

22. Lesher, Richard L., "Regional Dissemination Centers Program," NASA Program Review, June 2, 1965.

23. Watson, Thomas J., Jr., Testimony before the Ad Hoc Subcommittee on a National Research Data Processing and Information Retrieval Center, U.S. House of Representatives, May, July, and September 1963.

24. Sanders, Barkev S., "The Number of Patentees in the U.S.," Idea (Journal of the Patent, Trademark and Copyright Research Institute of George Washington University), Summer 1965.

25. Holman, Mary A., "Government Research and Development Inventions--A New Resource?", Land Economics, August 1965.

26. Ibid.

. On October 22, 1965, Senator Hart reported, on the Senate floor, that government-financed research and development produced more than 40,000 patentable inventions between 1945 and 1962. Nearly one-third of those were patented in the 1959-1962 period. The great bulk were made by private contractors whose research efforts were supported by the Federal Government.

. In January 1963, the National Aeronautics and Space Administration reported that its work, conducted both in government laboratories and private facilities, had led to 786 inventions. By August 1964, the number had increased to 2,500. And by May 1965 that number had doubled to 5,000.

The Astro-Nuclear Laboratory of Westinghouse Electric Corporation has disclosed that the reporting of patentable inventions by engineers within the corporation averages approximately 0.8 inventions per man-year of engineering effort. Those figures apply to discoveries which are potentially patentable and therefore presumably represent a higher standard of novelty and value than is necessary for the results of technical effort to have utility and value. But assume that an innovation ratio of 0.8 per man-year of effort is the standard for scientists and engineers employed in federal R&D programs. If that is the case, NASA alone--with 60,000 scientists and engineers in-house or under contract--will be generating 48,000 innovations annually. Assuming a ratio of considerably less than 0.8 per man-year of effort, federally supported programs, at the present rate of funding, would result in more than 100,000 innovations per year.

But volume of technology alone is an insufficient basis for justification of an effort to channel technology into the civilian economy--although it is one necessary indicator. As H. G. Barnett has pointed out:[27] "The size and complexity of the cultural inventory that is available to an innovator establishes limits within which he must function. The state of knowledge and the degree of its elaboration during his day,

27. Barnett, H. G., Innovation: The Basis of Cultural Change (McGraw-Hill Book Co., New York, 1953).

the range and kind of artifacts, techniques, and instruments that he can use, make some new developments possible and others impossible. The mere accumulation of things and ideas provides more material with which to work. A sizable inventory allows for more new combinations and permits more different avenues of approach and problem solution than does a small one."

It is clear that federal support of R&D has in recent years generated "a sizable inventory."

But how relevant to the needs of society are the items of knowledge stocked in that inventory?

Certainly, man's capability to accumulate and retrieve information has always paced his progress. But the sheer volume of information available today--unless properly managed in an organized system that permits the right information be found by the right person at the right time--may be tending to inhibit progress. That threat has been eloquently described by the eminent neurologist, Dr. Grey-Walter: "Facts accumulate at a far higher rate than does the understanding of them. Rational thought depends literally on ratio, on the proportions and relations between things. As facts are collected, the number of possible relations between them increases at an enormous rate."

Dr. Vannevar Bush put it another way: "Science may become bogged down in its own products, inhibited like a colony of bacteria by its own exudations."

The sheer volume of information being generated under government programs--and the lack of a set of integrated systems to evaluate, categorize, control, and disseminate it--makes Dr. Bush's distressing thought appear almost to be reality.

The man who has been forced, in the course of his work, to seek out that available information which is relevant to his objective, will readily attest to the maze of paths--most of them unmarked--which he must follow to uncover even a small portion of the information that is potentially relevant. And in the process, he is likely to be forced to sift through a great deal of information that is not relevant.

While significant strides in information management have been made in the last five years by such groups as COSATI, the Atomic Energy Commission, the National Aeronautics and Space Administration's Scientific and Technical Information Division, the Science Information Exchange, the Library of Congress, the Defense Documentation Center, and others (including a number of non-governmental organizations), the state of the art in information retrieval (as distinct from document retrieval) is still woefully inadequate. This question will be discussed at greater length later in this paper.

At this point, however, it is logical to indicate the size of the inventory of information in a quantitative sense. This is best illustrated by pointing to some standard measures of information volume:

. The last issue of the "World Bibliograph of Bibliographies" lists more than 100,000 separately collated volumes of bibliographies.

. There are now more than 300 specialized technical information centers in the U.S.

. More than 30,000 scientific and technical conferences are held each year throughout the world. Many publish proceedings.

. There are nearly 1,900 independent abstracting and indexing service organizations dealing in scientific and technical fields throughout the world, with 365 of them in the U.S.[28]

. Index Medicus, prepared by the National Library of Medicine, now lists around 150,000 titles annually.

28. Documentation and Dissemination of Research and Development Results, Report of the House Select Committee on Government Research, November 20, 1964, p. 16.

. Scientific and Technical Aerospace Reports (STAR), the NASA indexing guide to the world's unpublished reports in aerospace, carries about 30,000 new listings annually. The companion journal, International Aerospace Abstracts, which lists published articles in the aerospace field, contains about 28,000 new entries annually.

. Technical Abstracts Bulletin (TAB), the listing of new accessions in the Defense Documentation Center (DDC), carries nearly 1,000 new entries each month.

. During calendar 1965, DDC will process around 1.7 million document requests. It handled about 1.5 million document requests in 1964.

. In the last twelve months, the Science Information Exchange added 100,000 records of ongoing research tasks to its information bank. The bulk of these are in the life sciences. Total coverage of ongoing federally supported research in the physical sciences would easily more than double the inflow of information to SIE.

. The amount of scientific information published around the world every 24 hours would fill seven complete 24-volume sets of the Encyclopedia Brittanica--or 61,320 volumes per year.[29]

. At last count, in October 1962, the Federal Government employed 330 translators, 1,157 technical writers and editors, 337 archivists, and 3,311 librarians. Of course, not all of those personnel were engaged in working with scientific and technical literature. But the number has certainly grown substantially since that time--and a large amount of the technical information processing supported by the government is performed under contract.

. The National Science Foundation lists federal obligations for scientific and technical information for Fiscal Year 1966 at $258,673,000. However, total federal expenditures for scientific and technical information processing are far greater

29. Seaborg, Glenn T., Address before the Annual Meeting of the National University Extension Association, Washington, D.C., April 28, 1964.

than that. For example, NSF reports total obligations of the Atomic Energy Commission for this type of work at $5,474,000. The Atomic Energy Commission, however, estimates its total expenditures in this area for FY 1966 at $28,842,000. Of the total, formal budget items account for only $1,522,000.

Obviously, the volume of government-generated scientific and technical information has reached the stage where, without systematic information management and dissemination, the odds that an interested scientist and engineer could obtain the information he needs would be very low indeed.

The question then becomes this: Is the available information sufficiently relevant to the needs of society to justify investment--either public or private--in the means of making the right information available to the right person at the right time?

The next chapter deals with that question.

Is Government-Generated Technology Relevant?

It is obvious to even the casual observer that an extremely large technological base has been generated by the research and development programs of the Federal Government, principally the Defense Department, Atomic Energy Commission, and National Aeronautics and Space Administration.

But does this ocean of scientific and technological knowledge have any value in the context of the unmet community and human needs with which the National Commission on Technology, Automation, and Economic Progress is concerned?

Critics of existing programs to transfer technology from one industry to another or one discipline to another generally state the proposition this way: "If we spent billions of dollars to develop better home appliances, would we, in the process, get a man to the moon or build a better ballistic missile?"

The answer, obviously, is "no." But the wrong question has been asked.

A proper rephrasing of the question--which recognizes the nature of the R&D efforts of NASA, AEC, and DOD--would be this: "If we spent billions of dollars in research and development in every scientific and engineering discipline, is it likely that the new knowledge thereby generated might find wide applicability in helping to meet the problems of an industrialized society?"

Now the answer, obviously, is "yes."

Of course, if major R&D programs were initiated to specifically seek solutions to given problems outside the space/defense/nuclear realm, the odds in favor of generating specifically useful new knowledge would very likely increase.

But the priorities have been assigned. The nation is already committed to major R&D efforts in support of national defense, space exploration, and utilization of nuclear energy. For the purposes of this paper, then, the question is whether the results of that R&D might have secondary utility. The question is whether the problems and objectives outside the space/defense/nuclear realm in any way overlap those within that realm.

Certainly, there is overlap.

Is the overlap sufficient to justify an investment--public or private--in a means of funneling the relevant knowledge developed by DOD/AEC/NASA to secondary uses?

The authors believe available information is too meager for a definitive answer to that question. But there appears, on the basis of experience in technology transfer thus far, to be sufficient potential for secondary application to justify substantial investment in efforts to find a clear answer to that question.

There are numerous indications that new technologies being generated with public funds, in support of defense/space/nuclear missions, have substantial value in secondary applications. Among those indications are the following:

- NASA/DOD/AEC, in composite, are conducting or sponsoring research in every scientific and engineering discipline. That fact, alone, supports the judgment that the results of this research can be applied to meet a wide range of community and human needs.

- The small--and extremely youthful--programs that have been established (by NASA, AEC, and the Commerce Department) to channel scientific and technical information to private industry and other organizations have already borne some fruit. A few examples of successful transfers of technology by AEC and NASA appear in Appendices C and D.

. Those who have studied this question have concluded that the results of government-sponsored R&D do have potential relevance in secondary areas. Three such subjective evaluations appear as Appendices E, F, and G.

. The transfer of knowledge--from industry to industry, discipline to discipline, region to region, country to country, and culture to culture, and from generation to generation--has been a continuing process throughout the history of man. Technology transfer should not then be considered a new and untried concept. History proves its workability. However, the current thrust is to speed the transfer process--to shorten the time gap between the discovery of new knowledge and its application across a broad spectrum. A body of knowledge on how to accomplish this transfer process has not yet been developed and assimilated. This question is discussed in greater detail later in this paper.

The breadth of research and technological development being carried forward today by the Federal Government is partially indicated by the broad classifications of grants and research contracts NASA sponsors in universities and other nonprofit institutions:[30]

Physical sciences (physics, chemistry, and mathematics)

Engineering sciences (energetics, electromagnetics, fluid mechanics, materials technology, mechanics, system analysis and control, flight operations)

Cosmological sciences (planetary sciences, astrophysics, astronomy)

Socioeconomic studies

30. A more detailed understanding of the scope of NASA/DOD/AEC research and development activities can be obtained by the interested reader who will scan the categories listed in <u>Guide to the Subject Indexes for Scientific and Technical Aerospace Reports</u> (NASA, June, 1965) or who will examine several issues of <u>Technical Abstracts Bulletin</u> (announcement journal of the Defense Documentation Center), <u>Nuclear Abstracts</u> (which announces new information relating to the nuclear sciences), <u>International Aerospace Abstracts</u> (a guide to published literature in the aerospace field), and <u>Scientific and Technical Aerospace Reports</u> (the announcement journal for report literature in the aerospace field).

Scientific investigations in space (sounding rockets, scientific satellites, lunar and planetary exploration)

Satellite applications investigations (meteorology, communications)

Vehicle systems technology (advanced vehicle systems, booster recovery systems)

Supporting activities (tracking and data)

Space operations technology (manned space flight)

Space propulsion technology (solid rocket systems technology, liquid rocket systems technology, nuclear systems technology, space power systems technology)

Flight medicine and biology (biotechnology, operational aspects of in-flight experiments)

Basic medical and behavioral sciences (physiology, metabolism, radiology, psychology and sociology)

Space biology (effects of space environment on biological phenomena, extraterrestrial life)

In addition to the vast amount of new scientific and technical knowledge being generated in their programs, AEC, NASA, and DOD have--by necessity--developed a number of new management methods and analytical techniques that have applicability in other areas.

One such concept was spelled out by John Paul Stapp:[31] "Behind the headlines that hailed the success of each Project Mercury orbital flight was an organized effort actively involving more than 19,000 people with all degrees

31. Stapp, John Paul, "The World Science Will Create," Nation's Business, January, 1965.

of training and skill, deployed in 16 ground stations around the world, sailing the oceans in 28 ships and flying in more than twoscore aircraft. Never before in human history have so many people so widely separated worked together on a single scientific experiment. A revolution in scientific research and technological development, this highly organized systems approach has opened a new phase in man's development. The beginning of this scientific and technological renaissance merits more detailed consideration, particularly in its projected lines of development and future implications for the human race."

Systems analysis has direct relevance to such problems as design of mass transit systems, crime prevention, waste disposal, pollution control, regional resources development, and other areas of human needs where the important influences (political, social, and economic) are fragmented, the variables are many and their relation to one another is dynamic, and the technological requirements cover a broad spectrum.

A single innovation, of course, can have relevance in a multiplicity of secondary applications. For example, it seems reasonable that work NASA, AEC, and DOD have done in developing manipulators and devices to extend human physical capabilities might be applicable, to varying degrees, in each of five areas: (1) Prosthetic devices. (2) Material handling equipment for hot or difficult environments. (3) In ocean engineering and "underwater plumbing." (4) For automated industrial handling situations. (5) For small particle manipulation in laboratories and medical testing facilities.

The impact of a single innovation finding a single secondary use can also be felt in several areas. This has been illustrated by Philip Wright[32] in the following fashion:

32. Wright, Philip, <u>Final Report of 1964 Activities Relating to a Study Contract to Develop Dissemination Procedures for Use with the Industrial Applications Program</u>. (University of Maryland, College Park, Maryland, June, 1965).

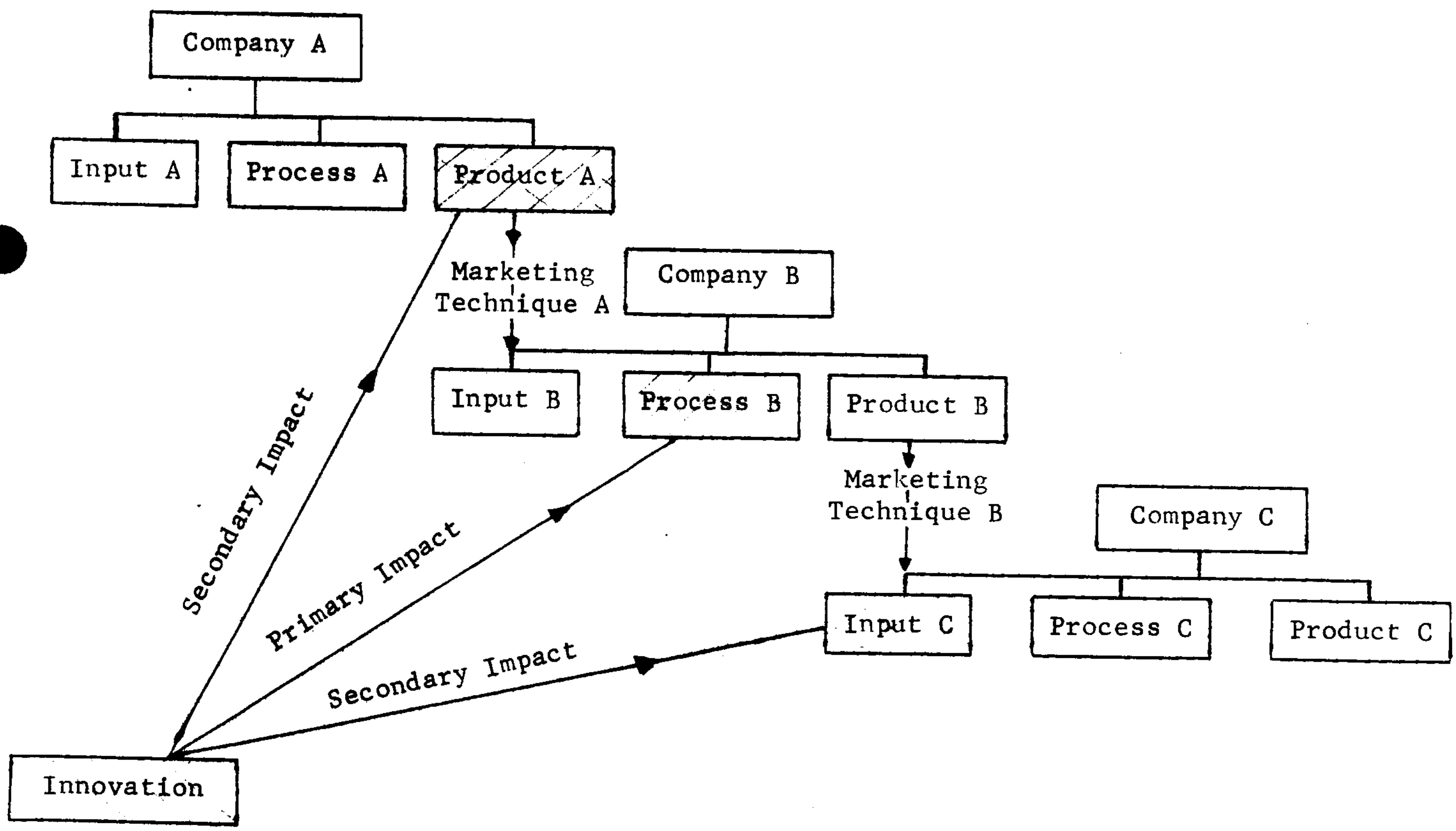
"If an innovation is a product, then, in addition to it being of interest to a manufacturer of similarly-related items (identical index terms), it can be of interest to some manufacturer, the process for whose product (different index terms) the innovation is a raw material or equipment input, too. Similarly, it can be of interest to another manufacturer whose product (different index terms) is a raw material or equipment input to the process of the potential manufacture of the innovation. The same considerations, of course, equally apply to processes and in addition, as has been noted earlier, all these products, either those of input relevance to the process for manufacturing the innovation, or the innovation itself for the product to which the innovation is itself relevant as input to the process for making it, be related to each other by the processes involved in making them. The different product marketing techniques are also very important and should be taken into account." (See Figure on the following page.)

It seems clear that a primary product of the space, nuclear, and defense programs is new knowledge--not just in a few fields but in every important discipline.

It also seems clear that a significant portion of that new knowledge can be applied in a multiplicity of other areas. Certainly, there is sufficient potential relevance to justify an investment in experimental efforts to attempt to match available knowledge to unmet human needs.

The question then becomes one of how to accomplish this channeling effort. That subject will be treated next in this paper.

INNOVATION/COMPANY RELEVANCE RELATIONSHIP
(A New and Improved Process for Making an Existing Product)



Why Technology Transfer?

Apollonius of Perga discovered conic sections in the third century B. C. They were applied to problems of engineering in the seventeenth century.

Paracelsus discovered the anesthetic effects of ether and Valerius Cordus gave out the formula for its preparation--but it was centuries before it was used as an anesthetic.

Non-Euclidean geometry, worked out by Riemann as an essay in mathematics in the nineteenth century was applied by Albert Einstein in the twentieth century in his theory of relativity.

Chlorinated diphenylethane was synthesized in 1874 but its value as an insecticide (DDT) was not recognized until 1939.[33]

In 1836, a combine--that mowed, threshed, tied the straw in sheaves and put the grain in sacks--was designed. It was based on technology that had existed for at least 20 years. But not until the 1930's--a century later--did such a machine appear on the market.[34]

An English patent for a "machine for transcribing and printing letters" was issued in 1714. Not until 150 years later--when Remington bought the patents of Latham Scholes--did the typewriter become commercially available.

33. Dryden, Hugh L., "Interaction Between Space Exploration, Science, and Technology," Speech before the Twin Cities Section of the American Institute of Aeronautics and Astronautics, Minneapolis, March 11, 1965.

34. Eco, Umberto, and Zorzoli, G. B., <u>A Picture History of Inventions</u> (McMillan and Company, New York, 1963).

The idea of changing sound into recordings was conceived in 1857 by Leon Scott. But not until 1889--32 years later--was the phonograph (based on Edison's designs) produced and sold.[35]

Those examples illustrate the generally experienced time lag between the discovery of new knowledge or articulation of a new concept and its practical application.[36]

Even with a modern climate that permits provision of some government development funds and an available defense market, there is a notable time lag. For example, it was six years from the invention of the transistor to the commercialization of the first transistorized amplifier.

That there should be time lags is natural. Technology does not spring forth in full bloom from the genius of a single discipline or single generation. It moves forward step by step, building on experience, drawing from a multiplicity of individual endeavors and growing steadily more complex, drawing its strength and applicability from an ever-widening range of human skills and an ever-expanding pool of scientific knowledge. Occasionally, several of technology's life sources converge, resulting in a quantum jump.

35. Reviewing the "19 most useful inventions between 1888 and 1913, S. C. Gilfillan, <u>The Sociology of Inventions</u>, (Follett Publishing Co., 1935, Chicago), noted these average time intervals: (1) Between conception of invention and patenting of first working machine--176 years. (2) To first practical use--another 24 years. (3) To commercial success--another 14 years. (4) To important useage--another 12 years.

36. There is some evidence that the time lag is growing shorter. Logic dictates that it should; the impetus for development is greater today than ever before. The impetus derives from the ability, today, to obtain government funding to aid in development of a wider range of devices than ever before; from the attraction of a larger mass market (to offset development costs) than ever before; and from keener inter-industry competition, forcing concentration on product improvement and product innovation.

But in a society as complex as ours, there are considerable elements of luck and coincidence in the meeting of the producer of new knowledge with the potential user. Occasionally, a man who has invented a micrometeoroid detector might overhear the luncheon conversation of a scientist in need of a means of detecting the heartbeat of a chick embryo.[37] But to rely on mere chance to bring about utilization of new knowledge would seem to be a most inefficient means of obtaining the maximum return on our large national investment in research and development.

Since early and widespread use of new technology can provide numerous national benefits--speeding economic growth, aiding our national defense posture, creating new employment opportunities, improving our international competitive position and our national prestige, enhancing the quality of our lives--it seems in the national interest to effect means of shortening the time gap between the discovery of new knowledge and its use. To do that requires systematizing communication between those who generate new technology and those who can apply it to meeting unmet human needs.

And in a society structured such as ours--a structure that encourages increased specialization--traditional means of communicating no longer suffice. When new knowledge was generated in smaller amounts and fewer fields, the professional journal provided an admirable means of communicating new knowledge. And when our industrial structure was less complex, the trade magazine provided a channel for communication of comprehensive information within industry. But specialization within disciplines and fragmentation of manufacturing activities have splintered those communication timbers. Where once one publication could cover a broad field, today 50 or more publications report on specific segments of that field. Not only has it become increasingly difficult to

37. The initial impetus for that transfer of technology came about in that manner; see Appendix C.

communicate across industry and disciplinary lines--it has become extremely difficult to communicate between fields of specialization within a single industry or discipline. An it is across such lines that new knowledge must flow if its optimum utility is to be obtained.

The new metal cutting method not only has relevance to the machine tool engineer, and to the metallurgist--but possibly also to the aircraft engine designer, the chemist who formulates coolants and lubricants, and maybe the surgeon as well.

The new adaptive control principle might be relevant to the steelmaker, chemical processor, machine tool builder, aircraft traffic control system designer, computer manufacturer, railroad operator, medical diagnostic equipment designer, and dozens of other professions in hundreds of industries with thousands of market orientations.

And, just as one innovation or bit of new knowledge can have applicability in numerous areas, so also the development of a new device or system may require inputs of knowledge from a multiplicity of endeavors. For example, the development of a composite material to solve a given problem might require the knowledge generated by such diverse professionals as a solid state physicist, a polymer chemist, a nonferrous metallurgist, a marine biologist, a corrosion engineer, a ceramicist, a technologist working in diffusion bonding, a ferrous metallurgist, and a paint chemist.

Knowledge is not provincial--but people sometimes tend to be. While new technology may have utility in diverse areas, it is likely not to be recognized unless deliberately brought to the attention of innovative people working in those areas, in an understandable form, and at a time when it can be given sufficient evaluative attention. A well-known economist[38] has put it this way:

38. Werner Z. Hirsch, in testimony on a National Economic Conversion Commission before the Senate Commerce Committee, June 22, 1964.

"Knowledge has no boundaries, unless they are artifically created, and even then they are not easily maintained. New knowledge, whether in the form of new ideas, processes, materials, or products, spills over from one person to the next. Knowledge has two negative effects that lead to great complexity and require enlightened public policy toward the spillover process. On the one hand, the fear that new knowledge will not long remain restricted in ownership dampens the willingness of private industry to invest in it even though such investment would be profitable from a national standpoint. On the other hand, spontaneous spillover appears too limited and too slow a process to permit the nation to benefit fully from its large investment in new knowledge. Spontaneous laissez-faire dissemination of new knowledge therefore leads to under-investment in private research and development and, while it produces growth, the latter is not as great and as fast as it might be."

Because a capability exists does not mean it will be used. Remember what the farmer told the book salesman.[39] And remember that when Baird called on the Marconi Company, he was told they could find no reason to be interested in television.[40] Optimum utilization of new knowledge will not take place as a natural process. One author[41] stated that case this way:

39. A salesman attempted to sell a farmer a set of books on improved farming techniques. The farmer's retort: "Shucks, I ain't farmin' half as well as I know how to now."

40. Moseley, op. cit.

41. Schmookler, Jacob, "Technological Change and the Law of Industrial Growth," paper based on "Changes in Industry and the State of Knowledge as Determinants of Industrial Invention," The Rate and Direction of Inventive Activity (National Bureau of Economic Research, New York, 1962).

"Any such explanation is in principle unsatisfactory, for it rests on the untenable premise that what can happen will. To assert that an invention is made because it was possible to make it, or that a commodity will be produced because it has been invented is on a par with the statement that the Golden Gate Bridge was built because the building art permitted it."

The case was summarized in a few words by Joseph A. Schumpeter: "As long as they are not carried into practice, inventions are economically irrelevant."[42]

His reasoning applies not only to inventions but to all potentially useful new knowledge. And his reasoning can logically be extended to say that when new knowledge is not applied to all those situations where it would be economically significant, the optimum return has not been achieved on the investment in the generation of that knowledge.

The research director for a welding equipment manufacturer pointed to one reason for the existence of time lags and at the same time made a case for investment in programs to transfer technology when he said: "Information must be used in packages; if all related pieces are not available, the incomplete package lies dormant for a decade or so until some key discovery rounds out the package."[43] (Even if all the pieces have been discovered, they must be available to the potential user, or the result is often as suggested here.)

The alternative is for some organization to fill in the missing pieces--but that is a risky proposition and is likely to occur only when the potential payout is exceptionally high and the chances for finding the missing pieces are comparatively good. The history of nylon offers one

42. Schumpeter, Joseph A., The Theory of Economic Development (Oxford University Press, 1961).

43. From The Impact of the U. S. Civilian Space Program on the U. S. Domestic Economy, Report of the National Planning Association, July, 1965.

good illustration. In 1935, after several years' work and many disappointments, W. H. Carothers, in the laboratories of the du Pont Company, produced the first nylon fiber and du Pont undertook to translate it into a marketable product. By 1939, large-scale production of nylon hosiery had commenced. Thus, in a matter of four years of development, du Pont had reached its appointed goal. Estimates put the total cost of the early stages of research and development at about $6 million; at that time 230 technical experts were engaged in the work. What precisely was involved in the development undertaken after Carothers' initial discovery?

First, it was necessary to find ways of producing on a large scale the intermediate constituents of nylon which, up to that time, had been made only on a small scale. The two important materials were adipic acid and hexamethylenediamine. Adipic acid had been manufactured in Germany for some time but there had been no commercial exploitation of it in the United States. The German processes were not readily adaptable to the plants of du Pont and it became imperative to develop a new catalytic technique for this purpose. Hexamethylenediamine posed even greater difficulties; it was merely a laboratory curiosity and had never been manufactured on a commercial scale before. Success here required the discovery of new catalysts and the proper handling of heat transfer problems. Next, a great deal of work had to be done at the stage where the materials react to form the long chain molecules of the nylon polymer. The first polymers were made in glass equipment in Carothers' laboratory, but glass equipment was completely unsuitable for commercial manufacture and metal equipment had to be designed. Methods of controlling the degree of polymerisation had to be evolved, since a failure to stop the reaction at precisely the right time resulted in the production of different and far less useful polymers than nylon. The technologists had to learn how to make one batch of the product exactly like another.

At the next stage of manufacture the flakes of the polymer had to be melted and some means found to transfer the molten mass to the spinning machines. Only pumping gave the filaments adequate uniformity, but unfortunately there were no existing pumps suitable for the task. A new type of pump was required embodying new alloys capable of withstanding the heat of the molten polymer. At the next stage of spinning, the machinery had to be specially designed for the task, since nylon could not be spun in the same manner as cotton, wool, viscose or cellulose acetate. The winding and the cold drawing processes also confronted the developers with problems which were novel and for which specially designed machines were required. Thus at each one of these stages--the mass production of what had formerly been made only on a small scale, the maintenance of unusual degrees of purity, the flexible controlling of the chemical processes and the devising of mechanical aids for handling materials with novel properties, the developers were confronted by one hurdle after another. It was only when the process reached the stage of knitting and weaving that existing and familiar techniques could be called in to help. But at every stage workers knew what they were looking for, and, with varying degrees of certainty, they knew it could be found.[44]

The critical point of the nylon story is that--while the discovery of nylon itself was of such overwhelming importance that its commercial potential demanded its translation into marketable products--the ability to manufacture nylon products efficiently was dependent upon numerous other, beforehand seemingly unrelated, pieces of technology.

The discoveries of extreme magnitude, those that lead to the creation of whole new industries for example, have sufficient inherent force to bring about their own exploitation. Like the gold coin in the coal bin, they're easily

44. Jewkes, Sawers, and Stillerman, The Sources of Invention (St. Martin's Press, New York, 1959), pages 21-22.

distinguished. But the incremental improvements in technology, which individually have seemingly lesser significance but which in composite underpin our industrial might, are less easily brought to the attention of those who can use them.

"Advances in industrial technology are generally based on small, but essential, improvements in current knowledge and practice. These changes are demanded by new requirements, either of cost or performance or both. Taken individually, such advances are incremental to existing technology and their significance is not easily recognized. In their totality, however, they are impressive. Only rarely does a technological advance occur which may form the basis of a new industry or revolutionize an existing industry. When such a breakthrough does occur, it usually so dominates the scene that its own force creates new markets. It is recognized and does not require special attention to promote."[45]

The point is reinforced by Robert A. Charpie, Director of Technology, Union Carbide Corporation: "Generally, the transference problem is most difficult when the technology represents a modest but significant advance. Under these circumstances, we find a major barrier may exist because the new information alone is not sufficient to provide the incentive for implementation by industry. Often it must be added to other concepts (perhaps some yet to be invented) in order to provide a new total picture which has economic significance."[46]

It seems clear that any mechanism created to transfer technology should devote some emphasis to identifying and communicating incremental advances.

45. Transferrence of Non-Nuclear Technology to Industry, A Committee Report to the Oak Ridge Operations Office, U. S. Atomic Energy Cömmission, July 2, 1965.

46. Private communication.

It is also apparent that only a relatively small amount of new technology will be rapidly transferred and utilized for secondary purposes without the existence of mechanisms specifically created to perform that function.

Or could the generators of the new technology themselves effect rapid and widespread utilization of that technology? The answer appears to be "no."

For one thing, not all of the generators of new knowledge have either the skills or the inclination to bring about the application of that knowledge.[47]

Also, many of the generators are located--both geographically and in terms of professional and market orientation--some distance from the focal points of effective utilization. As James Webb has pointed out:[48]

"People performing the actual work in the NASA centers and in the plants of NASA contractors are in the best position to recognize new departures in technology and techniques and to indicate the areas of potential application. But we must still rely on the business community to supply the "profile of industrial or consumer needs."

And a publication of NASA's Lewis Research Center notes:[49]

"The last ten years have seen a growing concentration of defense and space research and development and of the nation's scientists and engineers. This concentration is both in geographical areas and in companies that are not historically in industrial or consumer good fields. Thus an enormous body of technology is building up in concentrated areas that not only have no mechanism for transferring it to the general economy, but indeed have no mechanism to examine this technology against a profile of industrial or consumer needs."

47. The characteristics of successful "utilization technologists" will be discussed at a later point in this paper.

48. In Business Horizons (Indiana University), Fall, 1963.

49. Reproduced in Business Horizons (Indiana University), Fall, 1963.

The situation is aggravated by the fact that federal funds for research and development are heavily concentrated among a relatively small number of organizations within a few industries concentrated in a few geographical regions. If the generators of new technology were encouraged to bring about its commercial utilization without the assistance of disseminators deployed geographically and industrially, the tendency would be to accentuate whatever regional and inter-industry economic imbalances are brought about by the initial concentration of R&D performance. Such a set of conditions would lead to the attraction of talented people--especially those with entrepreneurial instincts--from regions without large R&D contracts to regions with such contracts.

Obviously an effective means of spreading new scientific and technical knowledge is through the migration of people possessing such knowledge. In the sixteenth, seventeenth, and eighteenth centuries, the movement of large groups of people was, in fact, the mechanism by which the diffusion of new technology took place. But The rate of diffusion was painfully slow.

At least 35 years after Abraham Darby had successfully burned coke in his iron smelting blast furnace, for example, many English smelters were under the impression that only wood could be used. Frenchmen first melted glass in coal furnaces almost a century after an English innovator had done so, and they acquired the secret of making flint or lead from the English after a lag of more than a century and a half.

The story of the Huguenots is also perhaps worth retelling to illustrate the point:[50]

Twenty-one days after Louis XIV revoked the Edict of Nantes the Great Elector Frederick William issued his famous Potsdam decree, written in both French and German.

50. Scoville, Warren C., "The Huguenots and the Diffusion of Technology," in The Development of Western Technology Since 1500, edited by Thomas Parke Hughes (MacMillan Co., 1964).

The Elector ordered his agents at Amsterdam and Hamburg to provide sustenance and transportation to all Huguenots who traveled that route to Berlin or other Prussian cities where they wished to dwell. Those who chose to enter his realm via Frankfort-on-Main could get money, boat passage on the Rhine, and passports from his agent in that city. The immigrants could freely choose their locality, occupation or trade, and the materials they would need to set up shop or build themselves a house. The Elector promised to provide them free of charge with any ruined dwellings and enough materials to repair them or to allow them several years' free occupancy of whatever empty houses they could find provided they set to work to construct their own. They might bring with them duty-free all their furniture, personal effects, and properties useful in their trade; they were accorded all city and guild rights which natural-born citizens enjoyed; and the Elector promised to grant them all privileges and tax exemptions which would materially help them start a new manufactory and even to advance them money, tools, and raw materials to do so insofar as possible. French nobles were to enjoy noble status in their adopted country; all were to have complete freedom of worship, and the government offered to pay the salary of one minister for each town; and until they became acclimated to their new legal and social environment special judges and courts were to be established to handle all legal difficulties which would arise among them or between them and their German neighbors. Members of the French military as well as men of letters received a most cordial welcome at court and were pensioned by the government. . .

In addition to the privileges granted them by the various governments, Huguenots settling in Germany received relief aid from funds raised by public collections and also from more ample funds supplied by sympathizers in Holland, Switzerland, and England. The Great Elector encouraged new enterprises by providing them with working quarters, some equipment, and loans without interest; by buying some of their output for himself and his court; and by clothing his troops in woolens produced by the refugees. He and other rulers levied tariffs on foreign goods which would compete with the new domestic products and exempted raw materials from local excises.

Most of the woolen shops begun by the Huguenots in Berlin, Brandenburg, Cassel, Erlangen, Frankfort-on-the-Oder, Halle, Magdeburg, and elsewhere were built on a small scale; but a few apparently employed scores of workers. One refugee from Rouen, formerly employed at Bobelins, carried with him the secret of dyeing fine woolen fabrics a bright red. Others began silk mills in a few places, introduced ribbon-weaving in Konigsberg, carried with them the art of printing calicoes, and introduced the manufacture of gauze into Brandenburg from Soissons. Some made the oils and liquid soaps so essential in washing the wools used in the better fabrics. Several Frenchmen complained that Huguenot refugees had been so successful in their attempts to manufacture linen fabrics at Hamburg and other places in Germany that they were taking the English, Spanish, and Indian markets away from the French and imitating quite well the famous products of Saint-Quentin, Laval, and Morlaix and that they were even likely to try to sell their output in France.

In those historical cases, the diffusion of technology by the mass movement of informed people was obviously effective. Equally obvious, it was slow.

And any modern governmental attempt to encourage mass movement of skilled technologists across regional and industry lines would seem to be politically untenable.

But the generators of new scientific knowledge and technological advances must cooperate in any program to channel new knowledge to its points of potential use. It is in their best professional interests to do so.

If they do not, Ralph Lapp's suggestion[51] may prove valid: "Is it possible that big science will become the victim of sheer size and bog down, dinosaurlike, in a swampland of its own making? No one--not even the most brillant scientist alive today--really knows where science is taking us. We are aboard a train which is gathering speed, racing down a track on which there are an unknown number of switches leading to unknown destinations. No single scientist is in the engine cab and there may be demons at the switch. Most of society is in the caboose looking backward. Some passengers, fearful that they have boarded an express train to hell, want to jump off before it's too late. That option, it would appear, is no longer open to them, but at least the passengers can discuss the matter among themselves and attempt to communicate with those up front. Hopefully, those in command may carry on a dialogue among themselves and keep a hand on the brake."

The point is twofold: First, the fruit of science and technology must somehow be delivered to the taxpayer's table if he is to be asked to continue to pay the bill for R&D. Second, the advance of science and technology depends on what has gone before. So the record of past and present knowledge must be made available to those engaged in the industry of future discovery.

The case has been stated in the famous Weinberg Report:[52] "Transfer of information is an inseparable part of research and development. All those concerned with research and development--individual scientists and engineers, industrial and academic research establishments, technical societies, government agencies--must accept responsibility for the transfer of information in the same degree and spirit that they accept responsibility for research and development itself. The technical community generally

51. Lapp, op cit.

52. <u>Science, Government, and Information</u>, Report of the President's Science Advisory Committee, January 10, 1963.

must devote a larger share than heretofore of its time and resources to the discriminating management of the ever-increasing technical record. Doing less will lead to fragmented and ineffective science and technology."

The point is reinforced: "If there is any gap in our research effort, it is in the area of converting scientific knowledge and engineering capability into civilian technology. We are all too ignorant of the mechanism of the transfer process."[53]

The same spokesman asserts: "The spread of scientific information is relatively rapid throughout the country and the world. Not so that of technology. Its spread has to be forced."

The scientist or engineer working the defense/space/nuclear community has an additional motivation for aiding in the technology transfer process. The civilian applier of his principles and techniques may, in the process of application, develop additional technology of value to the defense/space/nuclear community.

That point has been well made by H. Roy Chope of Industrial Nucleonics Corporation:[54] "Techniques and products which have been invented and created for industrial processes in turn provide unique solutions to defense or space problems. Extension of this self-funded R&D has now been applied to (1) precision mission tracking, (2) measurement of space radiation, (3) measurement of cryogenic fuels in missiles, and (4) guiding aircraft and helicopters." Hence, a full circle has been made. A federally created technology (nuclear technology) was further developed and applied to peaceful purposes with

53. Schrier, Elliot, "Toward Technology Transfer" (Report on a conference sponsored by the Engineering Foundation on Technology in the Civilian Economy, held at Proctor Academy, Andover, New Hampshire, August 5-9, 1963), in Technology and Culture, Vol. 5, No. 3 (Summer, 1964).

54. Testifying before the Senate Commerce Committee on June 10, 1965, in support of the State Technical Services Act of 1965.

private funds. The extension of the peaceful applications then provided new space uses which may not have been dreamed of by the practicioners of the original technology. "It seems to me that the basic goal of our technology utilization programs is to repeat the above story in sequence of events many times over," said Mr. Chope, adding, "Today there should well be concern about the lack of conversion of the vast amount of federally supported research and development into useful commercial and industrial products."

The point is clearly stated by Robert A. Solo:[55] "The value of information increases directly in proportion to the speed and breadth of its dissemination."

It might be useful to think in terms of "value added by transfer," much in the same sense as we recognize value added by transportation, value added by communication (publishing, broadcasting, etc.), and value added by retailing. Certainly, information has no value to a potential user unless he is aware of its existence. Further, its value to him increases as the information is assembled and delivered to him in terms of his language, interests, outlook, points of reference, set of values, and experience. And when the information is combined with other information that complements and supplements it--and the full package is delivered rapidly and in a meaningful form (related to the needs and objectives of the potential user), its value increases still more.

One measure of the economic value of having the right information available for the relevant purposes at the opportune time has been made by Allen and Andrien.[56]

55. Solo, op cit.

56. Allen, Thomas J., and Andrien, Maurice P., Jr., "Time Allocation Among Three Technical Information Channels by R&D Engineers," Report on an MIT research program in the management of science and technology under NASA and NSF grants, August, 1965.

They found, in studying four government-funded, parallel, R&D projects, that between 13 and 14 per cent of total time spent by the teams was devoted to information gathering.[57]

It seems clear that numerous significant benefits--economic and social--could be derived if mechanisms could be developed to effectively channel new technologies to the points where they could be applied to public benefit.

It is now necessary to examine the transfer process, looking at the incentives and barriers to transfer, the types of transfer processes that have been isolated, and the essential components of an effective transfer mechanism. That will be the focus of the discussion in the following chapters.

57. During the initial one-sixth of the project duration, the teams spent an average of 31 per cent of total time in information gathering.

The Transfer Process

Commercial utilization of government-generated technology is a very old story indeed.

About 3000 B.C., Sumerian metalsmiths saw how a new weapon, the ceremonial battle mace, made the royal bodyguards invincible against their foes. But history indicates it was more than a century before the religious mystique which surrounded the ornamentation and design could be discarded and someone was able to abstract the essential concept: namely, that a long handle with a bronze head enabled the warrior to smite his enemy harder than the foe could strike back with his stone hand-axe. At that point--the "Eureka" point in the transfer process--bronze hammers with long handles were introduced to replace hand held stones for metalworking.[58]

And Rosenbloom[59] cites other examples: the canning of food was first developed to preserve supplies for Napoleon's army. The electronic computer was invented and improved in a World War II military project.

But those were cases of "spinoff" and "fallout." The transfer occurred largely by chance--and seemed to take place in a short time interval only in the cases of extremely significant advances in technology--advances of the importance of the computer and food preservation.

"The modern temper," says Rosenbloom[60] "seems to demand more rapid evidence of civilian benefits."

That demand, as has been indicated in this paper, stems largely from increased concern with spurring economic growth coupled with a growing awareness (based on some evidence) that government-generated technology can be applied to civilian

58. Gadberry, Howard M., "The Need to Borrow Ideas from Other Industries," Paper presented at the Valve Technology Seminar, Midwest Research Institute, Kansas City, Missouri, October 21, 1965.

59. Rosenbloom, Richard S., <u>Technology Transfer--Process and Policy</u>, National Planning Association Report No. 62, July 1965.

60. Ibid.

needs and, in so doing, both the rate of economic growth and the quality of life can be raised. The demand also stems from increased governmental concern with the need to create new jobs for a rapidly expanding workforce and for those workers temporarily displaced by mechanization and automation. The demand also results, in part, from the cries for assistance emanating from those regions of the country that have not been able to attract large amounts of federal R&D dollars. These regions, often largely dependent for growth on consumer-oriented industries, see opportunities to enhance their growth rates by an influx from new technology created with public funds.

There is, then, an unwillingness to wait for new technology to "spill over" into the civilian economy. Instead, there is an increasing desire to catalyze the transfer.

But the perfection of an effective and low cost catalytic mechanism (or, more realistically, combination of coupled mechanisms) is a difficult and complex task. In the words of Dr. Charles Kimball, "it is one of the most intellectually challenging problems of our time."

The process by which transfer occurs can be simply stated: "Technology utilization...involves the use of technology developed for one purpose to fulfill a need elsewhere. It requires: (1) The knowledge that an advance has occurred in one field, (2) the recognition of its significance in a different field, and (3) the capability to make the required adaptations."[61]

The effective channeling of new technologies, then, demands more than document dissemination--and even more than communication of information from one point to another. For the assumption is that knowledge will not only be transferred--it will be utilized. And the process, it is hoped, will take place over a short time span with resulting significant benefits.

Therefore, "a change of approach must be in the offing. A change from an approach that views the transmission of the

61. Transferrence of Non-Nuclear Technology to Industry, op.cit.

results of space/military research into industrial application as a happy instance of spillover to one that views it as part of an immensely difficult task of social engineering."[62]

Certainly, teaching scientific and engineering courses is technology transfer in a sense. So is reading and putting to use technical information from reference books and trade journals. And so is the assimilation of new ideas at conferences and seminars. Technology transfers whenever a businessman puts to work the advice of his own R&D staff or of outside consultants and it transfers when U.S. experts impart their knowledge to the people of underdeveloped countries.[63]

Sometimes in those cases--and certainly in any effective program to channel space/military/nuclear technology into the civilian economy--a wide range of kinds of technology will be transferred, including inventions, discoveries, developments, modifications, concepts, and new uses for devices, processes, materials, systems and techniques.

Clearly, no one transfer technique will be suitable for technology of such variety.

The shape of the end results will necessarily also vary greatly.

Arthur D. Little Inc.[64] suggests four types of end results can be expected from programs presently underway within federal agencies: (1) Specific devices (such as the V-slotted screwdriver); (2) new techniques (such as a new welding method); (3) a body of material (such as improved methods and approaches to achieving reliability); and (4) scientific awareness (knowledge which may become part of the stock in trade of the practicing scientist as he does his work in the field).

62. Solo, Robert A., "Gearing Military Research and Development to Economic Growth," Harvard Business Review, November-December, 1962.

63. Arthur D. Little Inc., Technology Transfer and the Technology Utilization Program, January 22, 1965.

64. Ibid.

Denver Research Institute, in an early study[65] of the NASA technology utilization program, noted six types of contribution to the commercial sector: (1) Simulation of basic and applied research. (2) Development of new or improved processes or techniques. (3) Improvements of existing processes. (4) Increased availability of materials, testing equipment, and laboratory equipment (5) Development of new products. (6) Cost reduction.

Sumner Myers[66] has pointed to a more fundamental--and, seemingly, very significant--type of transfer. He sees such activities as the space program setting new standards of achievement for the entire technical community. He asserts that "the space program may be stimulating the process of technological innovation by changing professional norms and general attitudes." He suggests that "the very existence of the space program as a model of technological achievement may prove more important to the economy than either the multiplier effect of its investment or the spillover of its technology." He points out that "people are influenced by and tend to accept as their wants those goals and values shared by their reference groups. Space scientists and engineers are a reference group for industry's staff professionals."

Noting that "the chief factor making for innovation in a community is prior innovation," Myers contends: "Perhaps the most pervasive contribution of the civilian space program may turn out to be the strength it has given, at the firm level, to those who push for innovation. The people who are for innovation now have more significance and have stronger arguments than those who oppose innovation. This is not only true at the firm level but is also encouraging people to push for bolder social undertakings. Whether they approve of the particular goal of the space effort or not, they use it as a model of how things might be done--from curing cancer to rebuilding cities. As a political candidate[67] recently observed: It may well be that we will not solve the

65. Denver Research Institute, The Commercial Application of Missile/Space Technology, September, 1963.

66. In The Impact of the U. S. Civilian Space Program on the U. S. Domestic Economy, op. cit.

67. Timothy W. Costello, quoted in the New York Times, June 30, 1965.

problems of our cities until we mobilize the same kind of all-out effort that may land us on the moon." Myers adds: "The emergence of innovation as a cliche is but a recent phenomenon. Its recognition as an ideal--however imperfectly attained--is but the conventional wisdom describing profound changes in the society that, we believe, links an increased rate of innovation at the firm level to the model set by the space program."

The space program--and, to a lesser degree,[68] the atomic energy program--has established a new environment for innovation.

This is an important point. The climate must be conducive to entrepreneurship if any technology transfer program is to be effective. The innovator, or change-maker, must be accepted--even encouraged--by society if new concepts are to be exploited in the areas where they have the most promising potential.[69]

The significance of such a climate--one that permits social invention as well as technological advance--is pointed up by Jerome B. Wiesner:[70]

"There are increasing opportunities for important investments in the public sector of our country. These opportunities--which are really needs--are enormous in the fields of education, health, natural resources development, pollution and contamination control and in all of these research can make major contributions. Our problem as a nation is to find means to be as visionary and dynamic in the use of our natural resources, both physical and human, in dealing with these

68. The secrecy that has surrounded nuclear work prohibited the tremendous accomplishments of that effort from becoming the widely accepted norm of achievement that the space program has become.

69. Tradition and convention has long bound local governmental units, a group whose receptivity to new ideas will be significant if military/space technology is to be channeled toward the solution of such problems as transportation, pollution control, waste disposal, education, and crime prevention.

70. Testimony before the Senate Subcommittee on Employment and Manpower, Dec. 4, 1963.

common problems as the private sector has been in creating new products and improving productivity, or the government has been in the application of modern technology to the problems of military security or space."

Knowledgeable spokesmen, then, we have seen, are calling for social innovation to create useful mechansims to apply new knowledge to the needs of both the public and private sectors of the economy.

What kind of social invention is required? That question can only be answered after we understand the incentives and barriers to technology transfer. We have much to learn in this area. Little has been done to synthesize, assimilate, and extrapolate the findings--in sociology, psychology, the communication sciences, computer technology,and the many other fields of knowledge than can contribute to answering the question. Also, there has been, to date, only a sprinkling of applied research in this field.

And, while a great deal has been learned from experimental programs conducted by AEC, NASA, SBA, the Commerce Department, and others, these programs have not covered a very broad spectrum transfer techniques and channeling mechanisms, in relation to the number of such techniques and mechanisms that might be usefully attempted.

For example, little has been done to effectively foster the utilization, in the civilian economy, of the methods and concepts used to solve problems in the military/space sphere. But, David Allison and others have suggested: "The most important derivative of this (the military/space) R&D effort is likely to be a new ability to solve problems. Not strictly technical problems, but those involving a mix of components: Technical, managerial, psychological, social, political. If this is true, then we are unwise to watch for spun-off gadgets. Instead, we must develop the means and the wisdom to transfer an intangible."[71]

71. Allison, David, "Civilian Technology Lag," International Science and Technology, December, 1963.

It is an important point. Some of the problem solving ability has been transferred, of course, in the process of transferring items of technology. For most such transfer demands some degree (often large) of adaptation on the part of the receiver of the technology. At that point, there is often intensive communication between the purveyor of the technology and its recipient. In the process, the recipient gains additional insight into the problem solving and managerial concepts employed by the generators of the new technology.

As W. R. Purcell[72] pointed out: Almost anything (from the defense-space community) requires extensive adaptation to be effectively used (in the commercial sector). Extensive cross-communication is required to discover what elements of one world might be used to best advantage in the other. In defense-space, understanding the customer and his need is relatively easy--and fulfilling it is relatively hard; in most commercial markets, the opposite is true. The magnetron, originally used by defense-space for propogation of radar waves, is now being used as a source of radiant heat in microwave ovens sold to vending machine companies and to restaurants. In this case, obviously, both the customer need to which the product is addressed and the customer to which it is sold are quite different from the original defense-space need and customer. Thus the product, the men, and the companies working on it must correspondingly be quite different. Extensive adaptation is required in the move from defense-space to commercial markets. In such cases transfer is much less than direct. While there are some cases in which direct transfer of defense-space products to commercial use is possible, the greatest opportunities are in the indirect transfer of defense-space technological understanding, management techniques, and innovation orientation. Viewed in this light, the broad spectrum of transfer has contributed much more to commercial companies than is generally recognized, and it correspondingly offers much larger opportunities than most top executives realize.

72. Purcell, W. R., Commercial Profits from Defense-Space Technology (Schur Co., Boston, 1964, copyrighted by Teconomics Associates).

Sumner Myers takes a similar view:[73] "The NASA experimental programs often involve firms that would not ordinarily seek out technical help of any kind. Some interesting results have emerged through this process. These firms have had some of their problems solved--often with non-space information. They have also been shown that they have solvable problems they didn't know they had. The NASA program also provides a good setting for serendipity. For example, one R&D manager--after declaring in no uncertain terms that he couldn't use any of the space technology offered his firm--went on to relate how one of the men he met at a NASA-sponsored conference led him to the solution of a problem that had been bothering him for years. One is reminded that to discover anything you've got to be looking for something. The various transfer programs get people looking for something. This may not seem to be an efficient way to transfer R&D information but as yet no one knows how to organize the information-innovation linkage more effectively."

Significant transfer simply seldom occurs in the sense that a piece of hardware developed for military/space/nuclear use can be transplanted, intact, to another application.

More often, it occurs by imitation or analogy. Rosenbloom[74] describes the process this was:

If an invention has been utilized in an innovation in its source context, and if similar needs exist in a different context, the original innovation may be imitated. This is often the means by which the broadest social benefit from an invention is derived. This process of imitation is called the diffusion of innovation and has been extensively studied by social scientists during the past 50 years. Transfer by analogy poses distinctly different problems and is less well understood. Someone must first see an analogy between the characteristics of the original invention or innovation and the requirements of the new situation. Analogy underlies all inductive reasoning.

73. The Impact of the U. S. Civilian Space Program on the U. S. Domestic Economy, op. cit.

74. Rosenbloom, Richard S., op. cit.

It implies the identification of structural or functional identities and otherwise dissimilar situations or things. In one sense, analogy is at the root even of imitation of innovation. A farmer who considers trying the hybrid corn used by his neighbor must first come to believe that, with respect to those factors relevant to the use of the new seed, the situation is largely similar to his neighbor's. While that analogy may seem obvious, objectively similar situations are not always so perceived by involved participants. Transfer occurs by analogy when someone perceives a similarity between characteristics of a discovery or invention and aspects of a need or opportunity in a situation. Hence the conceptual representation of these things, in the language used to describe them, has an important influence on the likelihood that these analogies will be formed. If a turbo-jet engine is thought of as a source of heat or rotary motion rather than a linear thrust, a broader domain of possibilities is opened up. Application of a micrometeorite detector to the detection of heartbeats of embryonic chicks still within the shell is possible only when it is perceived that the required function and the actual function of the device both involve the detection of minute displacements of an object.

The foregoing emphasizes the need to avoid thinking of technology transfer efforts in terms of "fallout," "spinoff," and "Spillover."

Instead, more precise language must be used to demonstrate the various types of transfer than can occur with important end results.

Perhaps the use of the word "diffusion" would be good to describe that type of transfer where new knowledge is infiltrated throughout existing knowledge, displacing much that had been with what is newer and better, thus creating science and technology whose dimensions and utility are changed and improved.

Another type of transfer might be referred to, in metallurgical parlance, as "dispersion." This would describe those cases where discrete bits of new technology can be incorporated into an existing structure. Its use may be much different in the new context than its original application--but it can still be transferrable as a unit of knowledge or capability.

Other transfer phenomena can be made to occur--and each will demand different language for precise description. But the purpose of this paper is not to haggle over terminology, except insofar as the language used recognizes the complexity of the transfer process and the fact that it is an intellectual exercise of a high-order--not akin to picking up fruit from under the military/space tree, as words like "spillover" suggest.

Because effective transfer demands degrees of imitation, of concept displacement, of imagineering, adaptioneering, innovating, knowledge association, and extrapolation--because it is a process to which many diverse disciplines can contribute--and because it demands hard work on the part of both purveyor and receiver for its effectiveness, there are obvious barriers to its acceptance, and likewise, incentives are required.

"The real barriers," in the words of Dr. Charles Kimball,[75] "are neither financial nor technical. The barriers are outdated institutional practice, lack of entrepreneurship, and of reluctance to accept new ideas and new practices." He sees barriers to the transfer of technology in four major areas: (1) within corporate management--an unwillingness to take risks, the absence of adequate mechanisms to deal with all the implications of new products and new processes, an unwillingness to render existing plant and organization obsolete by adoption of the new, a concentration on the short term rather than the long term, and lack of knowledge of the government sources of new technology. (2) Within the scientific community--the Ph.D. who cannot communicate his findings or who has little economic understanding or drive, the inability to distinguish between the transfer of information and the transfer of documents, the confusion between publication and communication, the orientation of some scientists who seem to regard research as a special privileged way of life, and the scientist's inadequate appreciation of management's skills and functions. (3) In institutional factors--the lack of rapport between industry and universities, the unwillingness of some academics to relate their research to the needs of industry, the geographic separation of the generators of new knowledge from those who could employ it. (4) Within the human mind itself--creativity

75. Kimball, Charles, op. cit.

is generally thought of as an essentially individual endeavor but American society has moved in such a way that most things are done in groups, we have not yet learned how to provide the climate that fosters creativity, and there is a need for more people to become "innovation prone."

Denver Research Institute[76] has pointed to other gaps in our knowledge that pose as barriers to effective transfer of technology: (1) Communication channels through which technological knowledge flow are not understood. (2) How linkages between market information and technology actually occur in their various modes is not well understood. (3) New mechanisms need to be developed to bridge the gaps between organizations that have the technology and organizations that have commercial marketing capability. (4) There is insufficient knowledge of how technology is applied within the firm. (5) A better understanding of the role of government patent policy is required. (DRI sees patent protection as both a stimulus to technology utilization and a barrier.)[77]

DRI has summarized incentives and barriers to the transfer of technology as follows:

<u>Incentives or Stimuli</u>

<u>Individual</u>	<u>Institutional</u>
Salary	Profits
Invention awards	Diversification
Recognition and status	Organizational structure
Patents	Patents
Education	Personnel transfers
Dissemination media	Competition
Scope of Job responsibilities	Continuity of the firm
	Market Preemption
	Management sophistication

76. <u>The Commercial Application of Missile/Space Technology</u>, op. cit

77. Government patent policy is central to the ability to channel new technologies in promising directions. But it is a subject so complex and controversial that adequate discussion can not be devoted to it in this paper.

Barriers or Obstacles

Individual	Institutional
"Not invented here" concept	Uncertainty and risk
Reluctance to change	Reluctance to change
Time consuming paper work	Lack of knowledge
Narrowness of interest	Government regulations
Lack of knowledge	Capital requirements
Isolation	Proprietary data
Complexity and sheer mass of data	Security regulations
Limitations of the human mind	Organizational rigidities
	Incompatibilities between government and commercial R&D and production

Another compilation of the barriers to utilization of new technology frequently encountered in private companies has been made by Philip Wright.[78] The barriers were brought to light when Mr. Wright invited companies being offered new NASA technology to state their views about the difficulties involved in the effective transfer to industry of new technology for the purposes of its commercial utilization there.

- The Discouraging Effect of Abortive Reviewing of Technical Information
- Difficulties of Evaluating Advantage
- Difficulties of Assimilation
- Inhibiting Effects of Companies' New Idea Reception Procedures
- Cheerless Effect of the High Cost of Evaluation
- Frustration Owing to Delays in Response to Questions
- The Impediment of the Difficulties of Locating
- Adverse Effects of Inadequate Disclosures
- Adverse Results of Unfavorable Economics
- Barriers Owing to Educational Deficiencies
- The Obstructing Consequences of Inadequate Finances
- Adverse Influence of Government Policies
- Obstructions Owing to Impractical Nature of Innovations
- Difficulties Owing to inappropriate Orientation of the Presentation of Technical Information
- Discouraging Effects of Limited Applications
- Inhibiting Effects of the Absence of Information About Applications

78. In a report to the NASA Office of Technology Utilization on activities of the Office of Industrial Applications at the University of Maryland, a NASA regional dissemination center.

- Hampering Situations Created by Company Disinterest in Non-Exclusive Licensing
- Adverse Effects of Inability to Devote Time to Evaluation
- Deterrent Effect of Obsolescence
- Impeding Outcome of Weak Patents
- Handicaps due to Poor Communications
- Deterrent Effect of Proprietary Design Ownership
- Obstructing Impact of Security Regulations
- Preventative Effects of Fear of Lawsuits.

Edwin Mansfield examined the influence of seven characteristics of a firm and its operation on the rapidity of adoption of new techniques. His findings:[79]

- The speed at which an innovation is introduced increases with the size of the firm.

- The higher the expected return from an innovation, the quicker the innovation is likely to be adopted.

- There may be some relationship between the speed at which a firm is growing and its responsiveness to innovation.[80]

- There is no clear relationship between a firm's level of profitability and the rate at which it accepts innovation.

- There was no statistically significant relationship between the age of a company's management personnel and its willingness to accept innovation.

- There appears to be no significant relationship between a corporation's liquidity and its response to innovation.[81]

- The trend of a company's rate of profit was not found to be a significant factor.[81]

79. Reported in "Innovation in Individual Firms," Review of Data on Research & Development, Number 34, National Science Foundation, June, 1962.

80. Mansfield found no significant correlation here. Others however, have. See Bohlen and Beal, How Farm People Accept New Ideas (Iowa State College, 1955), and Hildebrand and Partenheimer, "Socioeconomic Characteristics of Innovators," Journal of Farm Economics (May, 1958).

81. Mansfield's sample for testing of these hypothesis was limited.

The findings of all these investigators point up the importance of the social environment in acting as a stimulus or barrier to innovation. The problem must be recognized, or the objective defined, or the goal established if innovation is to be applied without considerable suasion. In other words, all the technology necessary to providing the optimum means of controlling air pollution can be available but it is not likely to be applied until society recognizes air pollution as a major problem; people communicate their desire to have the problem solved to those who can influence action; those who are influential recognize the availability of the technology; the economics are found to be permissive; and the balance of power among those who influence the decision swings in favor of an early and effective solution to the problem.

That is, of course, a gross simplification of an extremely complex and dynamic situation. But the central point needs emphasis: The specific social environment must be receptive--and preferably active--for technology to be effectively transferred and applied.

Dr. Hugh L. Dryden[82] has made the point this way: "in my reading of the history of scientific development, I have been impressed time and time again by the almost dominant role of the specific social environment in which the scientist and engineer work, which in most instances seems to be a pre-requisite for the intensive development of the scientific concept itself as well as the ensuing technology. One or two examples will illustrate.

Most of the work for which Pasteur is famous originated in the social needs of the community in which he worked. Beginning in 1854 he addressed himself to the reason for unsatisfactory results obtained in the fermentation of beer, and in 1857 showed that the troubles arose from small organisms which interfered with the growth of yeast cells responsible for fermentation. Later he turned his attention to similar problems in the production of good wine. Later, under great social pressure, he studied the small organisms responsible for certain diseases of the silkworm, of cattle, of chickens, and of dogs and man. Thus social needs provided the incentive for and the support of Pasteur's scientific work in solving the "problems of the infinitely small."

82. Op. Cit.

Another classic story begins with the work of James Maxwell starting about 1850 and already briefly referred to. In 1865 and 1873 he described the propagation of electromagnetic waves and suggested that light was a phenomenon produced by the travel of electromagnetic waves in the ether. I believe the first experimental demonstration of electric waves was by Hertz in 1883, who invented an oscillator to produce such waves. There was some limited further theoretical and experimental development by scientists such as Lodge and Righi in the last two decades of the nineteenth century. Marconi began a study of the application of electric waves to signaling in 1895 and succeeded in sending signals across the Atlantic in 1901. I think it is now obvious to everyone that this application by Marconi to a practical social need marked the beginning of greatly increased support for theoretical and experimental research in this field, that it marked the foundation of very large industrial developments, and that there has been a very great social impact.

These cases are of course the traditional ones that everyone quotes. There are many others such as the development of probability theory and modern statistics from the "social need" of the members of high society in France interested in gambling.

From the foregoing, four conclusions can be readily stated:

(1) **For technology to be effectively transferred, the climate must be receptive to innovation and change.** Thanks partially to the space program having become widely accepted as a standard for achievement or a reference point for scientific and technological excellence, such a climate does exist in the U. S. today, at least to an acceptable degree.

(2) For technology to be efficiently transferred, there must exist recognizable specific social needs to which it can be applied. This condition, too, seems right. Certainly, the list of social needs frequently cited--a higher rate of economic growth, pollution abatement, improved mass transportation, better health care, more effective crime prevention, more systematic and sanitary means of disposing of wastes, improved education and training methods--are recognizable to the majority of U. S. city dwellers and a great many rural residents as well.

(3) The process by which technology can be transferred from its point of origin to utility in another context is an extremely complex one. Too little is known about the total process; no readily accessible body of knowledge exists. But empirical knowledge is being generated by existing experimental programs.

(4) An awesome list of barriers to acceptance of innovation has been compiled by those who have practiced transfer or studied the transfer process. Some of the barriers will likely always exist and need only be recognized in the design of transfer programs. Others, once recognized, can be prevented by designing transfer methods that avoid them. Still others can only be changed by evolution of the environment. And others likely appear as barriers only because we know too little about creativity, innovation, human behavior, group dynamics, and the processes by which ideas become accepted within organizations.

What is Government's Role?

If we accept that it is in the national interest to attempt to channel new technologies in promising directions, the next obvious question is who will perform the channeling function.

This paper will make no firm recommendations on the extent to which this function should be conducted in the public sector. But the authors will raise some of the questions, attempt to define some of the issues, and report on the degree of government involvement in past and present programs of this type.

A central issue is the degree to which the Federal Government should accept responsibilities for direct action programs to stimulate economic growth.

Another central issue is the degree to which the government should accept responsibility for the active development of national resources. The point here is that logical arguments can be made that technological knowledge has become as important to regional and national economic health and growth as were natural resources in the past. Those favoring substantial government involvement in programs to transfer technology argue that the precedent for such federal involvement is in past and present government programs to make rivers navigable; to aid in the exploration, use, and conservation of the nation's mineral supplies; and other such programs. Those who believe in that approach find reinforcement in the oft-quoted words of Alfred North Whitehead: "In the conditions of modern life, the rule is absolute: The race which does not value trained intelligence is doomed. Not all your heroism, not all your victories on land or at sea, can move back the finger of fate. Today we maintain ourselves. Tomorrow, science will have moved forward yet one more step, and there will be no appeal from the judgment which will then be pronounced upon the uneducated." Proponents of government involvement in programs to channel new technology into the civilian economy see in that quotation much dramatic currency. And they suggest that technology transfer is akin to both effective use of natural resources and education--activities that have long been deemed at least partially in the public province.

Those who look upon technology transfer as an advanced form of educational activity also find reinforcement for their views from Thomas Jefferson, who wrote: "To furnish the citizens with full and correct information is a matter of the highest importance. If we think them not enlightened enough to exercise their control with wholesome discretion, the remedy is not to take it from them but to inform their discretion by education."

A third question concerns the question of regional balances. Arguments have been made in favor of government support of programs to transfer technology on the basis that such programs will tend to offset regional imbalances in technological sophistication resulting from the concentration of federal R&D funding in a relatively few states. Ralph Lapp[83] has made two comments on this question:
(1) "Science points the way to the future for advanced industries and those states aspiring to technological status will gradually slip into an "underdeveloped" condition unless they gear themselves to the pace of modern science."
(2) Failure of the government to help the states develop their own capabilities may result in pockets of intellectual poverty and aggravate their economic plight. There seems to be little doubt that industry of tomorrow follows the research path of today." But Lapp suggested that "unless a state deliberately chooses to be at the tail end of research activity, it can act to get its 'fair share' of big science and--we must add because of the engineering angle--massive technology."[84]

83. The New Priesthood, op. cit.

84. Ibid

A fourth question--and a thorny one--involves the issue of whether government support of programs to transfer technology to the private sector of the economy would tend to work in favor of the marginal producer. The argument is that such government involvement would be interference in the private economy because it would tend to bring to the marginal company a partial capability that must otherwise be gained through relatively high investment on the part of the company.

A fifth debate centers about historical precedent for government involvement in programs to promote scientific activity and technological achievement, and to bring about the diffusion of science and technology throughout the economy. Appendix H lists some of the key events in this area, from the Constitutional Convention to 1950. The heavy emphasis has been in the agricultural--rather than urban and industrial--sphere.

It seems in order to mention a few of the events that are frequently cited as precedents for government action in the diffusion of science and technology.

One of the first patent applications under the Patent Law of 1790 was for "a mixture which was supposed to help make salt water fresh (through a distilling process)." Thomas Jefferson, who was then Secretary of State and as such was also the administrator of the patent law, proved by experiment "that the fresh water came from the distilling process, long known and used at sea, and that the mixture added did not enhance its efficiency. Nevertheless, Jefferson suggested to Congress that instructions for building an evaporator be printed at government expense and distributed to all shipmasters."

"That Jefferson should propose the dissemination of the knowledge thus incidently called to his attention suggests that the federal government had a duty to promote the general welfare by broadcasting this useful bit of information."[85]

Later, as President, Jefferson attempted to breathe new life into the dream first held by Washington et al, of a national university. In his plan, he proposed both 'research and instruction,' combining the advancement of knowledge with the 'dissemination of its rudiments'. This proposal, of course, was not accepted.

The national university would have represented a fairly broad approach to diffusion of scientific and technical knowledge, while the actual approach was piecemeal through such vehicles as the patent acts, Lewis and Clark expedition, Coastal Surveys, and the establishment of the West Point Military Academy in 1802.

Another piece of evidence of the concern of government with science and its fruits is embodied in the history of the Smithsonian Institution. James Smithson, a British chemist who had inherited considerable wealth and who died in 1829, stated in his will: "In the case of the death of my third nephew, I then bequeath the whole of my property... to the U. S. A., to be found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men."[86] To diffuse knowledge, Joseph Henry, first secretary of the Institution, proposed a series of reports on new discoveries in science, and the changes made from year to year in all branches of knowledge not strictly professional." He also published costly research works in the Smithsonian Contributions to Knowledge and in Henry's own summary of the Institute's

85. Fairand, Max, <u>The Records of the Federal Convention of 1787</u> (New Haven, 1911-1937), p. 12, as taken from <u>American State Papers</u>, Misc., I, 45.

86. Ibid., p. 66, as taken from Rhees, <u>The Smithsonian Institution</u>: <u>Documents Relative to its Origin and History</u>, (Smithsonian Institution, Washington, 1879).

contributions, he made "three fundamental distinctions with regard to knowledge, which must have an important bearing on the future advance of science in this country; namely, the increase of knowledge, the diffusion of knowledge, and practical application of knowledge to useful purposes in the arts."[87]

Those examples are only a few of the scores of federal ventures into the application of science. The point is clear that the Federal Government has long been involved. And the mandate has not been based solely on military preparedness. Instead, from the beginning, there has been the implied, and often expressed, conviction that science and knowledge should be exploited by and for all mankind.

One of the more forceful arguments for government involvement in programs to channel new technologies into civilian applications rests on the dual points that (1) the government is the generator of the vast bulk of new science and technology, and (2) a significant point of potential use for the new technology is in those activities generally considered to be wholly or partially in the public sphere. This case was stated as follows by the National Academy of Sciences:[88]

It is clear that with increased urbanization and industrialization, our country is developing a number of problems that can only be faced on a national basis--for example, education, air pollution, water resources, weather forecasting and control, pesticides, radioactive wastes, public recreation, natural resources, air traffic control, highway safety, and urban transportation. The degree of federal responsibility in these areas will always tend to be a matter for political debate, but there is greater consensus that the Federal Government has a responsibility

87. Dupree, A. Hunter, Science in the Federal Government (Harvard University Press, Cambridge, 1957), p. 3.

88. Basic Research and National Goals, a report by the National Academy of Sciences to the Committee on Science and Astronautics, Washington, D. C., March, 1965.

for seeing that the foundations of knowledge are laid in these areas than there is that it has an operational responsibility. Research related to these social goals tends to be recognized as a federal responsibility even when operation or regulation is delegated to the state or local level or left to private enterprise.

Another frequently heard argument is that the Federal Government should support vigorous efforts to transfer technology because it has a responsibility to the taxpayer to ensure the optimum return on the public investment in research and development. While the goal is desirable, the logic of the argument is debatable. If the secondary beneficiaries of the new technology can make optimum use of it without artificial stimulation, then government assistance would not seem warranted. History shows, however, that optimum use is not likely to occur naturally. And history proves quite emphatically that there will likely be a longer time lag between development of new technology and its civilian application via natural processes than would occur with some form of catalytic action.

Several students of innovation and technology transfer have voiced their opinions on the proper role of government in the process. We will next examine a representation of these.

The Engineers Joint Council has stated[89] that the proper role of government in technical information is to define the nation's needs, to assess how well these needs are being satisfied, to insure that information generated in government-supported programs is efficiently disseminated, and to coordinate and catalyze efforts in the private sector of the economy to deal with its information problems.

The Social Science Research Council suggested[90] that "more attention perhaps should be given in developing government research plans and budgets to making certain

89. Documentation and Dissemination of Research and Development Results, Study Number IV, Report of the Select Committee on Government Research, U. S. House of Representatives, November 20, 1964, p. 7.

90. Ibid.

that these will guarantee that data collected at considerable cost are kept available in usable form for re-analysis by government or private research workers once the report or other purpose for which the data was collected has been served. (Otherwise the investment of the government in such information) may serve only an immediate and limited purpose."

Elliot Schrier, in reporting on an Engineering Foundation conference on the topic, noted:[91]

"We need organizations for the transfer of technology parallel to those we have for research, engineering, production, and marketing. Whether within or without the corporate structure, the organization should be charged with the function of matching corporate needs, resources, and goals with the needs, resources, and goals of the economy at large.

"What is the role of the federal government in organizing for technology transfer? In developing new technology for its special needs, the government acts as instigator, participant, regulator, and consumer. Policies and agencies have been developed to promote relatively effective performance in each of these roles. Attempts to transfer technology to private industry, however, are relatively underdeveloped--and often contradictory.

"We need new legal and organizational means of accomplishing non-proprietary technical advances involving several companies in a single industry and even several industries. Present public policies, as interpreted by the Justice Department and enforced by the regulatory agencies and the courts, severely limit the amount of cooperation industrial organizations feel they can maintain without penalty... At the same time, our tax laws might be liberalized providing greater benefits to companies supporting programs of technology transfer through industrial associations, research institutes, or the universities.

91. Schrier, op. cit.

As an example to its contractors and private industry, the federal government should devote a portion of its research budget to furthering applications of the results."

Jerome B. Wiesner has given his views on the subject:[92]

"In my view, development activities, the creation of useful new devices, should only be undertaken if there is a clear-cut requirement for a new product after it has been developed. This is reasonable, for it is ordinarily possible to make satisfactory predictions about the probable cost and performance of a proposed new device, be it an aircraft, a computer, a chemical processing apparatus, or a nuclear power plant. Consequently, it is also possible to make a decision about the desirability of a given development. Furthermore, because development efforts are generally much more costly than research, one should apply rigorous tests of need before starting new efforts.

"In the case of exploratory development and applied research, there is reason to be more venturesome. Here the search is to see if practical applications of new knowledge are possible. For example, there is a vast and varied effort today to explore possible new uses of the laser, the source of coherent light developed recently, and the elements of this work should be carried to the point of demonstrating the feasibility of underlying concepts. Here, too, work beyond such a point should be permitted only if the ultimate capability is needed. These criteria are applicable to all but the basic research segment of the research and development effort. In other words, a basis exists by which administrators and legislators could establish the need for more than 90 per cent of the federal expenditures for research and development. I am not saying that they could or should pass on the technical validity of proposals or judge between competing ways of accomplishing a given objective. This will still be the function of experts, but then the experts will be passing on means, not ends. Corporation executives, government budget officers, and department heads and Members of Congress have

92. Wiesner, Jerome B., "The Role of Science in Universities, Government, and Industry: Science and Public Policy," <u>Proceedings of the National Academy of Sciences--Centennial: Fourth Scientific Session</u>, p. 1206.

traditionally made such decisions with confidence, and with access to scientific and engineering advice, there is no reason why they cannot continue successfully.

"But the choice in the field of basic research must be left to the scientists. This is why I place so much emphasis on the matter of distinctions. Even here, others will need to make decisions regarding the over-all level of effort, and if that level is less than is required to support all of the worthwhile research that scientists want to do at any given time, it will be necessary for the scientists to make decisions regarding the support for the different disciplines."

Rosenbloom analyzes the situation in this way:[93]

"Although the existence of some federal responsibility in this area seems beyond doubt, there is a serious question of degree. Since two-thirds of all R&D work is supported by federal funds, the government clearly has a responsibility to make the results of this work available for the widest possible use. An important question remains unanswered. How far should the government go, not only in making findings available, but also in selecting and tailoring reports for most effective use by private enterprise and even in promoting the receptivity of private enterprise for utilizing the advanced technology?

"A national system for technical information which would truly contribute to innovation must include institutions and procedures suited to the variety of functions for which the technologist uses technical information. Resources should be available to assist in answering specific questions in relation to already perceived problems. Furthermore, other mechanisms should serve to stimulate new ideas, to help identify latent needs, to keep engineers up to date, and to confirm tentatively-held propositions. Such a system should retain the pluralistic character of our present situation, while evolving toward more useful

93. Rosenbloom, op. cit.

responses to new needs and new capabilities. The government cannot, even if it would, create such a system unilaterally. But it should take the initiative in establishing a dialogue between producers and users, between government, business, and university establishments to clarify the joint understanding of the nature of a system that would be responsive to modern requirements.

"The question arises as to how far the government program should go in winnowing out the great bulk of material without potential commercial utility and in translating reports on new military and space technology into forms more nearly tailored to the potential needs of the recipients. It is possible that this function might be better performed by some intermediaries between government agencies and the potential users of the information."

The Weinberg Committee report[94] indicated a view of the role of government when it made the following recommendations to government agencies:

(1) Each Federal Agency concerned with science and technology must accept its responsibility for information activities in fields that are relevant to its mission. Each agency must devote an appreciable fraction of its talent and other resources to support of information activities.

"Each of the mission oriented agencies ought to become 'delegated agents' for information in fields that lie within their missions. In these fields, the agencies should maintain a strong internal information system and should support non-government information activities, always striving to blend the government and non-government systems into a consistent whole."

(2) To carry out these broad responsibilities, each agency should establish a highly placed focal point of responsibility for information activities that is part of

94. <u>Science, Government, and Information</u>, op. cit., pp.4-6

the research and development arm, not of some administrative arm, of the agency.

"We stress that the technical information activities of an agency must be part of research and development, not part of administration."

(3) The entire network of government information systems should be kept under surveillance by the Federal Council for Science and Technology.

(4) The various government and non-government systems must be articulated by means of the following information clearinghouses: (a) current efforts clearinghouse (SIE and the establishment of a new technological efforts exchange), and (b) report announcement and distribution (a la Commerce Clearinghouse), and (c) retrospective search and referral service.

(5) Each agency must maintain its internal system in effective working order. (To do that, the Committee suggests that technical reports should be referred or otherwise screened before they enter the technical information system; that agencies insist that their contractors live up to their contractual obligations for adequate technical reporting; that problems of security and declassification be studied by an ad hoc group of the Federal Council; that agencies such as NASA and DOD undertake critical review journal ventures similar to that of the AEC; that the large central agency depository should concentrate on being a document wholesaler and that the job of preparing state-of-the-art reviews and otherwise interpreting the literature should be the responsibility of specialized information centers where they exist;that agencies concerned should actively sponsor and support additional specialized information centers at appropriate establishments.)

(6) Problems of scientific information should be given continued attention by the President's Science Advisory Committee.

"Science and technology can flourish only if each scientist interacts with his colleagues and his predecessors, and only if every branch of science interacts with other branches of science; in this sense science must remain unified if it is to remain effective.

"Inasmuch as the Federal Government now supports three-fourths of all science and technology of the United States, the heavy responsibility to prevent our scientific-technical structure from becoming a pile of redundancies or contradictions simply because communication between the specialized communities or between members of a single community has become too laborious. Moreover, since good communication is a necessary tool of good management, the Federal Government, as the largest manager of research and development, has a strong stake in maintaining effective communication.

Only the Federal Government interacts with all of the elements of our information system.

"Another reason for the Federal Government's interest in maintaining the health of our scientific communications system has to do with the validity of our science. Modern science and technology cost our society dearly, and our society is justified in demanding its money's worth."

"In some discussions of the advisability of establishing a single Department of Science, deficiencies in the scientific communications system have been invoked to help justify the merging of all government science into a single department. But this is surely an oversimplification of a perplexing problem. Whether bringing the Government's total information system under a single organizational roof would improve communication is, in the first place, conjectural; in any case, even if the desired improvement were thereby achieved, better management of research and development would not automatically follow. Information is one of many tools that the manager of research and development must have; the use to which he puts the information--indeed the diligence and responsibility he shows in unearthing needed information--is determined only by his own skill as a manager."

"The ultimate aim is to connect the user, quickly and efficiently, to the proper information and to only the proper information. But perfectly precise switching is neither possible nor desirable. One cannot define in advance exactly what information is proper; the switching system must always allow for some browsing in neighboring areas. Moreover the capacity of the user to absorb information limits the system. Thus the information switching system, to be effective, must be more than a passive switch: it must select, compact, and review material for the individual user so that he actually assimilates what he is exposed to, and he is not exposed to too much that is unimportant or irrelevant. Its fundamental task is switching information, not documents.

"Science can ultimately cope with the information expansion only if enough of its most gifted practitioners will compact, review, and interpret the literature both for their own use and for the benefit of more specialized scientists."

Almost everyone who has seriously studied the question agrees that the Federal Government has some responsibility in bringing about secondary applications of technology generated via public funds. The question is the degree to which the government should go. This is one of the many areas in our economy in which it is difficult to get programs under way because of the confusion between the proper roles of the public and private sectors. These difficulties seem greatest in those areas where the responsibility is shared. Technology transfer is, it seems clear, one of those areas. And the precedents for successful sharing are few.

With the hope that existing programs might, in composite, show some pattern of legislative understanding of the degree of public responsibility in this arena, the authors spent considerable time examining the more significant ongoing programs in the various federal agencies whose statutory responsibility embrace technology transfer efforts to any significant degree. We will now report on those findings.

The authors familiarized themselves with ongoing programs aimed at the diffusion and utilization of government-generated science and technology in each of the following agencies:

- Department of Agriculture.
- Office of Science Information Service, National Science Foundation
- Defense Documentation Center.
- Atomic Energy Commission.
- National Aeronautics and Space Administration.
- Clearinghouse for Scientific and Technical Information, Institute for Applied Technology, National Bureau of Standards, U. S. Department of Commerce.
- National Library of Medicine.
- Office of Technical Resources, National Bureau of Standards, U. S. Department of Commerce.
- Science Information Exchange, Smithsonian Institution.[95]
- National Referral Center, Library of Congress.
- Small Business Administration.
- Government Printing Office.

95. While officially a part of the Smithsonian Institution, SIE is supported in large measure by the National Science Foundation.

The authors also examined, to some degree, supportive technical information programs conducted by the following Federal Government organizations:

- Committee on Scientific and Technical Information (COSATI).
- Army Research Office.
- Office of Naval Research and Naval Research Laboratories.
- Interagency Committee on Oceanography.
- Bureau of Mines.
- U. S. Coast Guard.
- Bureau of Customs.
- U. S. Geological Survey.
- Federal Communications Commission.
- Federal Aviation Agency.
- Bureau of Reclamation.
- Office of Saline Water.
- National Institutes of Health.

Appendix I carries brief statements on a random sampling of agencies that have technical information programs but no active efforts to broadly disseminate the technology they generate.

The various programs currently under way within federal agencies range, in degree of government participation toward achievement of technology utilization, over a very broad spectrum. In fact, several orders of magnitude--in terms of level of effort and level of support involved--separate the programs of some agencies from those of others. And within some agencies, several different levels of effort are apparent.

Obviously, there is a need for a more clearly defined national policy in regard to technology channeling efforts. Let us pose the potential role of government in the process in terms of eight distinct levels of effort--all of which are representative of ongoing programs in one or more agencies at present:

Should the responsibility of the Federal Government end with...

...Publication, i.e., making the results of research and development available (as in libraries, depositories, and journals) for interested parties, but placing the full burden of discovery and use on the potential user?

...Or with bibliographic control, i.e., making it easy for the interested parties to seek out relevant publications?

...Or with dissemination, i.e., actively delivering relevant publications to interested parties?

...Or with communication, which implies some personal (vs. only paper) involvement in defining the needs and objectives of the user and seeking to match specific technical information to those needs, so that understanding is achieved?

...Or with education, which implies not only communicating specific information but also building the background of the recipient of the information to a level where the information of specific relevance can be more effectively utilized?

...Or with encouragement, i.e., actual continuing consultation with the user of the information to promote utilization (vs. transfer, per se) of the technology?

...Or with assistance, i.e., government aid in adapting the technology generated for a government mission to make it useful for a non-governmental mission (or one government agency adapting technology generated in performing its mission for the use of another government agency in the performance of its mission?

...Or with development assistance, which implies government action to add to the knowledge base and develop new technology specifically to meet needs and objectives in the civilian economy?

Obviously, national policy in regard to technology utilization programs has been established in an ad hoc manner. Perhaps the time has come to reexamine all ongoing programs of this nature to determine the value of each in relation to the accepted or recommended responsibilities of the Federal Government.

It is not recommended that any national policy to be established limit governmental involvement to any one of the eight levels of effort outlined above. To do so would be to place undue emphasis on some sources and uses for technology and too little emphasis on others. Certainly, it would seem that the Federal Government has a legitimate role in developing weather satellites and medical research equipment (the ultimate level of government involvement) and at the same time has some responsibility for making available (perhaps only by storage) the results of the seemingly least useful R&D conducted by it.

What is recommended is that a national policy spell out the conditions under which federal agencies should conduct, foster, or support programs at each of the various levels.

But before any such policy can be established, certain questions should be considered. Among such questions are the following:

. To what degree, if at all, can known innovators employed by government agencies be diverted from their primary missions to assist in the transfer of technology--by, for example, speaking at seminars (<u>dissemination</u>); by conducting short courses (<u>communication</u>); by serving on task forces to adapt mission-generated technology to uses in the missions of other government agencies (<u>interagency assistance</u>); by giving advice and counsel to scientists and engineers in private companies and other governmental bodies who have a demonstrated capability to utilize it (encouragement); by sabbatical leave to champion an area of technology; by personal in-house development of innovations not oriented to the mission of his employer agency (development assistance)?

. To what degree should control of technology transfer efforts be centralized? This question, it appears, cannot be answered on the basis of available information and should be the subject of detailed and careful study.

. How can technology relevant to the problems and objectives of external groups be identified by the originating agency? This function is, of course, mandatory for the success of a technology transfer program. One approach used by NASA--stationing "Technology Utilization Officers" at facilities responsible for the generation of technology--has been effective. Should other agencies be encouraged to carefully select capable personnel to perform in a similar role?

. Much of the science and technology generated by government is of a very complex and sophisticated nature. In its primary form--the technical report--it frequently is readily understandable only by scientists working in the same specialty. But external utility might be in industries or disciplines much different from that of the researcher who generated the technical report. Should government serve an interpretive function in such cases?

. Efforts to effect the utilization of new technology for economic advancement would be greatly enhanced by a better understanding of the processes (and varying modes) by which new ideas become accepted and innovations adapted for use in various organizations that would be expected to utilize the results of government research and development. Sufficient fragmentary evidence exists to permit the formulation of several hypotheses. It is proposed that the Commission recommend detailed analysis of the innovative process and searching study of the environmental factors that contribute to entrepreneurship. The results of such studies would be extremely useful in developing the most effective means of channeling new technologies in promising directions.

. Smaller businesses, which generally have limited scientific and technical resources, pose a special problem for those concerned with the non-governmental utilization of government-sponsored research results. NASA, for example, has designed its technology utilization program in such a way that much of the dissemination activity will eventually be self-supporting (i.e., paid for by the beneficiary rather than the originator of the technology). But smaller businesses have difficulty justifying expenditures for this purpose--even though the cost is relatively low. (The larger organization generally not only has better in-house capability to interpret and understand the implications of new scientific information but also has a broader technology consumption pattern, i.e., its technical interests are less specialized, generally, than those of the small company.) Effective, low-cost, means of serving the needs of smaller businesses--without subsidizing them in opposition to the principle of open market competition vis-a-vis the large companies with which they complete--should be explored. Currently, NASA and AEC have joint programs with the Small Business Administration under way on an experimental basis. These programs may provide some understanding of how to cope with the seemingly special needs of smaller business.

. An important point in effecting technology utilization is to have a thorough definition of what technology is available for use. This demands efforts to pinpoint innovations and new knowledge, to describe such innovations and knowledge in terms understandable to potential users in many industries and many disciplines, and to arrange all such knowledge in a system that permits the potential user to find what he wants without having to sort through a lot that he doesn't want. (This argues for computerized systems, due to sheer volume, and it argues for switching devices among various systems.

This function is necessary for even the lowest levels--<u>publication and bibliographic control</u>--of government involvement in true technology transfer (as differentiated from mere publication).

. The most effective forms of technology utilization demand a personal champion of the technology. This argues for wider use of a type of specialized information center not commonly found, i.e., a center staffed by articulate, knowledgeable, adaptive, extrapolative "missionaries" who can communicate an understanding of new technology and encourage its use. The cost of such efforts, it would seem, should be borne in large part by the users of such systems. But the initial investment is heavy. Should the government help with "startup costs?"

. Most potential users of government-generated technology seem unaware of the channels through which such technology can be made to regularly flow to them. There appears to be a need for local or regional focal points, i.e., places to which any qualified seeker of knowledge can turn for guidance in obtaining that knowledge. Such "referral centers" might function as pipelines to smooth and expedite the flow of new technology into promising potential applications.

No ready-made answers of substance exist for any of those complex questions. All demand careful study--and such studies should probably involve the originators of the technology (for example, representatives of the Defense Department, Atomic Energy Commission, National Aeronautics and Space Administration, National Science Foundation, and National Institutes of Health), the potential users of the technology (in private industry), in government agencies at the federal, state, and local levels, and in universities), those with experience in transferring technology (for example, research institutes, universities, and publishers), and those who must, in the end, determine the policy (legislators).

When a national policy has been decided upon, the question may still remain as to where to ideally house the function or functions within the Federal Government.

It is highly likely that the single agency to perform the function would not be the best solution. Too many different levels of activity and too many different kinds of mechanisms will be required for effectiveness to permit such an easy solution. Centralizing the responsibility would also seemingly place the obligated agency in a most uncomfortable position vis-a-vis other federal agencies. To transfer technology, one must have some technology to transfer. For one agency to police the activities of other agencies to the degree necessary to ensure the reporting of new technology would seem to place the entire program in jeopardy. (Discussions relevant to this issue have occurred in relation to the establishment of a National Research Data Processing and Information Retrieval Center[96] and in relation to the oft-proposed establishment of a Department of Science.[97]

96. Hearings before the Ad Hoc Subcommittee on a National Research Data Processing and Information Retrieval Center of the Committee on Education and Labor, U. S. House of Representatives, May, July, and September, 1963.

97. This proposal has been debated at various times for 85 years. In the 1880's, it was proposed and the issue resolved by the Allison Commission, a joint Congressional Commission, which concluded that the government's scientific establishment and the scientific community in the universities had already grown too complex for such a change in organizational structure.

While it might readily be feasible to assign some abstracting, indexing, publishing, referral, and document dissemination functions to a central agency, intensive efforts that demand in-house adaptation and development as well as thorough understanding of the technologies involved are probably best left to the agencies originating the technology.

Between those two extremes (represented on the one hand by the Clearinghouse for Scientific and Technical Information and on the other by the Atomic Energy Commission's fostering of civilian nuclear energy generating capability) lies much ground for debate. It is possible that social inventions of a high order will be needed to meet the requirements of effectiveness and efficiency. Certainly, such recently established efforts as the Atomic Energy Commission's Office of Industrial Cooperation, NASA's Office of Technology Utilization, and the Commerce Department's State Technical Services Program will provide valuable empirical evidence, some years hence, of the relative effectiveness of various experimental approaches. Meanwhile, interagency cooperation and exchange of knowledge gained should be encouraged organizations such as COSATI might be assigned some responsibility for collecting and synthesizing the knowledge gained through these programs.[98]

98. And through other important activities, such as those carried forward by the Small Business Administration, the Science Information Exchange, the NSF Office of Science Information Service, the National Referral Center of the Library of Congress, the extension services in the agricultural field, and the several programs of the institutes within the National Institutes of Health.

Some Existing Programs

This section of this paper reports on some existing federal programs to channel technology--or technical information or documents--from originator to potential user.

While no existing program shows promise of becoming a full answer to the need for a mechanism to channel new technologies in promising directions, several of these programs can provide valuable experience in the design of better systems--and some of the existing programs can likely become components of a national system that might be designed at some future date.

Following are reports on some of these programs:

Science Information Exchange

SIE is primarily an inventory of current and ongoing research tasks. It can therefore tell a practicing scientist or engineer who else is working in his field and give him a brief sketch of what each of the other investigators is doing.

A component of the Smithsonian Institution, SIE is funded principally by the National Science Foundation.

SIE's main method of operation is to obtain copies of detailed proposals or work statements for R&D from various federal agencies, write descriptions of each task expected to be performed in that project, and categorize the tasks in terms of the various disciplines and topics to which the research might be relevant.

SIE was established to serve R&D program managers in federal agencies, helping them to avoid duplication, establish priorities, maintain balances among related research fields, locate special research capabilities, and perform other useful tasks.

The existence of the information, however, allows SIE to perform a kind of technology transfer function--in that SIE will tell any qualified scientist or engineer who else is doing work in a field of interest for that scientist or engineer. SIE thus serves a referral or clearinghouse function--or acts as a coupling mechanism among technical men with similar interests in different disciplines, industries, sectors, and regions.

With a full-time staff of around 100 or so people, SIE handles a whale of a lot of information. Of the total staff, 46 are scientists and engineers doing analysis. A staff of eight handles the data processing--with an SIE-operated computer system in-house. Another eight people make up the administrative staff. The rest of the work is clerical.

SIE got its start in 1949, when rapidly expanding government programs in medical research caused several agencies (NIH, ONR, and others) to voluntarily establish, via interagency agreement, a Medical Sciences Information Exchange. In 1953, the mission was broadened to become the Bio-Sciences Information Exchange, and the Smithsonian Institution was asked to run the program.

In 1960, the mandate was enlarged to include the physical sciences and the organization was renamed the Science Information Exchange. It now has two divisions--Life Sciences and Physical Sciences (and some work in the Social Sciences is being brought into the stream).

Since 1949, the Division of Life Sciences has accumulated approximately 300,000 records of research grants, contracts, projects, and tasks.

In 1962, the Division of Physical Sciences was organized and began the collection of information on current basic and applied research in chemistry, physics, mathematics, earth sciences, materials, electronics, and engineering sciences.

During the past year, SIE added 100,000 records to its information bank. Of that 100,000, about 25,000 were proposals - some of which were eliminated when the proposal was rejected.

SIE differs significantly from Library, Documentation Center, and Technical Reference Service operations in a number of respects. SIE is concerned only with records of research, planned or in progress. It does not receive progress reports, abstracts, or other forms of published research results.

All information is supplied to SIE on a voluntary basis. However, SIE has been quite effective in the life sciences without having to perform an extensive soliciting function.

An exceptionally high degree of cooperation has been provided to SIE by the National Institutes of Health and the Department of the Interior. At NIH, information is provided to SIE at the time NIH receives each new proposal. The Department of the Interior has issued a directive that every project undertaken by Interior or sponsored by Interior must be reported at the earliest date to SIE.

Information about each research task, planned or in progress, is registered on a single page, "Notice of Research Report," by SIE professional analysts. This page contains the following information:

(1) The name of the supporting agency - and the name of the supporting bureau or office, and, if it is multiply funded, the name of the cosponsors.

(2) A specific title for the project.

(3) The names, departments, official titles, and locations of the principal investigators and all other professional people engaged on the project.

(4) The name and address of the institution conducting the research.

(5) A 200-word summary of the proposed or undertaken work. (The summary is used as a means of communication and is written by a scientist or engineer who is familiar and closely associated with the research task. The summary describes the problem, shows the relationships to other aspects or to broader areas of research, identifies the plan of procedure, the techniques, the instruments and special materials, the organisms of other biological preparations used, the special environments, and other such relevant information. Each record summarizes a single research task or a discreet unit of research so that it may be analyzed and indexed in technical depth and detail for effective use.)

(6) If work is being performed at a location other than the institute of the recipient, the sheet indicates where the work is being done.

(7) The startup date for the research and the planned conclusion date of the research indicated.

(8) The annual level of effort in dollars is indicated.

(9) If the project is multiply funded, the annual dollars support for each sponsor is given where practical.

Dr. Monroe Freeman, Head of SIE, notes that titles for research are seldom meaningful. He notes that it is also essential that a scientist or engineer experienced in the general area of the research is the best qualified person to write the analytical summary.

The 200-word summary of the research is then indexed with 1 to 45 descriptive words for each project. This is not a key-word-in-context approach. Dr. Freeman feels that would be too limiting.

In the life sciences, Dr. Freeman estimates that 90% to 95% of all the research underway - 45,000 to 50,000 tasks annually - that is of a federally-funded nature, is brought into the SIE information stream. Comprehensive coverage of the physical sciences has not yet been achieved.

SIE deals only in unclassified and unlimited research.

Currently, SIE has arrangements with 125 private funding groups on a full cooperation basis. In other words, such organizations as the Ford Foundation and the Cancer Foundation report on their research projects to SIE. Dr. Freeman points out that there are 72,000 non-taxable foundations in the United States. He conservatively estimates that 5,000 of those support some research. He says that around 300 of those support a significant amount of work. He is hopeful that SIE can get the full cooperation of those 300 groups. It now has 125.

Another area of input that SIE is beginning to seek is that from state and local governments. There is almost no cooperation with SIE on the part of state and local governments now. There has been little attempt to recruit such cooperation to date. However, Dr. Freeman is optimistic about the potential results here after a program of suasion.

The SIE charter specifically says that it is not to be an international information exchange. But SIE is permitted to accept anything volunteered from abroad. So SIE never asks overseas organizations to assist it (which might morally commit SIE to service those organizations). However, SIE is now getting about 1,000 life science items per year from Canada (by title only) and is getting some cooperation from groups in other foreign countries who have voluntarily written to SIE and offered to provide information. For example, the New Zealand Forestry Service read an article about SIE in a technical magazine and sent SIE 175 items. The national council on building research in Spain sent all of its work to SIE voluntarily.

The priority for service from SIE is as follows:

1. Federal agency requests.

2. Requests from grantees and contractors to federal agencies.

3. Requests from U. S. citizens in the scientific and engineering community.

In addition to its referral function, SIE provides other kinds of services. These are:

1. Preparation of "catalogs." There are two types of catalogs: the first is a listing of all projects supported by a single agency with the projects indexed according to a predefined method established by the sponsoring agency.

The second type is where SIE has the job of collection--and the major intellectual task of organization and editing. These catalogs are multiagency and multidisciplinary. A good example is the water resources catalog that was prepared at the request of the Department of the Interior and is now being sold by the Government Printing Office.

Catalogs are prepared by SIE for government agencies only. They are not prepared for individuals or for government contractors. However, at the option of the agency making the request, these catalogs may be provided to the public at large through the Government Printing Office or in some other fashion. SIE has 18 such catalogs in preparation now.

2. Compilations. The second form of output is what SIE calls "Compilations." These are simply computer print outs of work in a given field. For example, a job currently under way involves preparing a compilation to show all work under way that relates to the mobilization of urban resources.

3. Specific Topical Searches. This is a case where a scientist or engineer in the field wants to find who else is working in his specific field. He will phrase his question to SIE and will get a summary sheet for each of the ongoing projects in his field of interest.

4. Name Searches. This is the simplest kind of service offered by SIE. It is provided to program managers and project officers in federal agencies. It helps them in selecting grantees and contractors and in allocating research priorities. For example, a program manager or an awards committee in a federal agency may have 150 applications for grants. They will send those 150 names to SIE. SIE will conduct a computer search of all its information and provide to the requester a package showing how many ongoing research projects each of the 150 people has, in what agencies, and what level of funding, how far toward completion they are, and other salient information.

During 1964, SIE answered 5,000 questions of the Type 3 kind. That is, they told a scientist who else was doing what work in his field of interest. (SIE mailed a questionnaire to 600 users of that specific kind of service and 97% said they had learned of ongoing work in their field as a result of this SIE service.)

During the last 12 months, SIE has supplied--on request--about one million full-text copies of the summary sheets of ongoing work.

Atomic Energy Commission

The Atomic Energy Commission has had, since its inception in 1946, a vigorous program for the dissemination of unclassified scientific and technical information to encourage industrial usage. The Commission has provided consulting services, training, and other assistance to the nuclear industry.

Recently, AEC has decided to extend the boundaries of its industrial cooperation program to encourage consultation with respect to non-nuclear applications of the AEC's nuclear-oriented work and to allow the use of the AEC's facilities, equipment, and services in the performance of limited research and development work toward non-nuclear industrial applications.

For that purpose, the Atomic Energy Commission has established an Office of Industrial Cooperation--to serve as a bridge between the laboratory and industry. The Office is charged with carrying out the following functions:

(1) It should actively search for items of information and disseminate this information to industrial organizations.

(2) The Office should make itself aware of the needs of particular sections of industry.

(3) The Office should encourage the industrial participation program.

(4) Industrial consultation will be arranged through the Office.

(5) Visits by representatives of industrial organizations will be arranged by and through the Office.

(6) The Office will work with such local organizations as now exist which will be suitable for its general purposes.

(7) The Office will work closely with the library department of the Argonne National Laboratory.

The major difference in the Atomic Energy Commission's Technology Utilization activities since the establishment of the Office of Industrial Cooperation is that the Argonne National Laboratory is making overt gestures toward industry to enhance the transfer of non-nuclear technology resulting from nuclear R&D.

The following statement comes from the first semi-annual report of the Argonne Office of Industrial Cooperation, January 1 to June 30, 1965: "An observation which occurred quite early was that the size range of the transfer items in the companies to which technology can be transferred is very great. For example, a transfer item can be anything from an experimental boiling reactor to a thickness gauge; or anything from a voting machine to a Holmium Heat Sink. It can be a finished product ready for production or an idea. An entire new company can be created and therefore be a transfer item as is the man who takes a skill to the company. The industries involved in this business of technology transfer may range in size from General Electric or duPont--companies with sophisticated research capabilities and interests--to a two - or three-man production shop with no research capability or interest. This means that the system which is set up to transfer technology from government research to industry must be flexible and versatile enough to cover these wide ranges.

"It is also observed that there are two essential components of technology transfer. These are an automated information retrieval and dissemination system and a personal contact. The information pile-up has become so great that information is essentially lost unless a selective dissemination system is perfected. In addition to the identification and location of information, there must be a personal contact between the source of information and the industrial user. This personal contact serves several functions. He can help locate information, aid in adapting it for use, and probably more important, convince the industrial user that the available information could possibly be of use to him."

In the Atomic Energy Act of 1954, the Congress established policies that bear upon making available to industries, for non-nuclear uses, the results of the AEC's research, development, and industrial operations. Section I of the Act declares it to be the policy of the United

States that: The development, the use, and control of Atomic Energy shall be directed so as to promote world peace, improve the general welfare, increase the standard of living, and strengthen free competition in private enterprise." Section I 4-b sets out the principle that "the dissemination of scientific and technical information relating to atomic energy should be permitted and encouraged so as to provide that free interchange of ideas and criticism which is essential to scientific and industrial progress and public understanding to enlarge the fund of technical information."

In keeping with that national policy, the Commission strongly supports the objective of assuring the maximum availability of the results of government-generated research for beneficial use of the civilian economy. Reports Dr. S. G. English, Assistant General Manager for Research and Development, Atomic Energy Commission: "Our national laboratories and other principal contractors have been encouraged to take all reasonable steps to promote the transfer of the results of AEC technological developments to the civilian sector. In 1964, a copy of the implementation of this policy was extended beyond application for nuclear-oriented purposes into the area of potential use for non-nuclear purposes. This underscores our recognition that our ideas, inventions, developments, processes, techniques, materials, equipment, instruments, etc., which resulted in AEC research and development should be available for use throughout the national economy."

The Commission also publicizes newly developed technology through special symposia and meetings. An example aimed at non-nuclear applications was a recent series of meetings and training sessions conducted by the Office of Industrial Cooperation of the Oak Ridge National Laboratory in Oak Ridge, Tennessee.

As of April 27, 1965, the Atomic Energy Commission had issued 1,069 non-exclusive licenses for private use of 557 patents.

The overall purpose of the Commission's isotopes program is to develop and demonstrate applications of isotopes and radiation technology which were important to the national economy and welfare. The program also includes the production and distribution of isotopes in types and quantities necessary to ensure that through AEC and industry efforts, national requirements are satisfied, and to provide for the development of technology for the production, separation, and purification of isotopes by using both AEC and industry sources.

The Atomic Energy Commission has been using 13 different means of transferring the results of its R&D efforts. These areas were recently reported upon in an AEC study of its technology transfer activities. Excerpts from that report follow:

DTI Services. AEC's Division of Technical Information is the only AEC information program which has a specific "line-item" budget appropriation. Its most important services are:

Publication of five quarterly Technical Progress Reviews dealing with civilian power reactor and isotope technology.

Publication of the semimonthly "Nuclear Science Abstracts" which is the world's most comprehensive abstracting and indexing service devoted to nuclear science and engineering.

Publication of books and monographs, 12 to 15 per year.

Management of the Engineering Materials Program, which makes available drawings, specifications and design criteria.

Management of AEC's publication distribution network.

Coordination with other government agencies, including the Clearinghouse for Federal Scientific and Technical Information.

The Division of Technical Information also monitors information exchange agreements with foreign governments, services AEC's 93 domestic depository libraries and 88 foreign depositories, supports research on information handling systems, and provides a variety of consulting and printing services.

Topical Reports. AEC encourages contractors to publish topical reports. These are often annual reviews of the status of programs at the various sites. For example, each division at the Oak Ridge National Laboratory publishes an Annual Report. These reports provide a rapid means of information dissemination, compared to the technical journal route, and are convenient digests of program activity.

Technical Journals and Meeting Papers. Almost all of AEC's contracts provide specific encouragement for scientists and engineers to publish unclassified findings in the open literature. Indeed, one measure of the effectiveness of a national laboratory can be taken by examining its contributions to the literature.

The chief value of this mechanism is that it tends to keep science "honest" because the literature is critically refereed and subject to open criticism. Unfortunately, the very strength of the system is also its weakness, since the channels of review usually make the process slow and laborious. In addition, there is also the problem that the utility of journal articles is very often limited, for commercialization purposes, because the practical aspects of the technology are often not spelled out.

Trade Journals. Probably the most widely read items of technology are those which appear in trade journals. This is an attractive mechanism, for more than others it tends to get the right kinds of information to the right people. AEC-funded technology naturally appears in journals specializing in nuclear development. Only occasionally does it appear in others, such as those in the metalworking field or those more business oriented.

Seminars and Information Meetings. Almost all AEC facilities conduct regular seminars and information meetings. However, only a limited number of such meetings have been held for the express purpose of transferring AEC-sponsored technology to industry. This type of meeting is normally held when the AEC has a need for a specific product or service and wants industry to provide it.

Advisory Boards. There are currently 21 committees and boards which provide advice and guidance to AEC. Most of these advisory committees are concerned with specific programs or problems, such as Nuclear Cross Sections Advisory Group, Computer Advisory Group, Reactor Physics, Biology and Medicine, etc. The members of the committees are leaders in their respective fields, and as such provide a subtle mechanism for the transfer of information.

Information Centers. At the present time there are twelve specialized information centers located throughout the AEC contractor complex. Each operates in a very specific, very narrow range and is designed to be the most complete repository of information in its field. The centers provide the usual library services, technical consultation, state-of-the-art reports, translations, and even propose experimental work.

Consultation Services. AEC policy provides for several types of consulting services to industry on a nondiscriminatory basis.

One type of service, more properly identified as a conferring service, is the short-term affair such as the need for clarifying information on requests for bids, or an inquiry relating to a published article. No charge is made for this kind of contact.

When formal consultation is required, such as involving the solution of a specific technical problem, a somewhat more regulated approach is used and costs are recovered by a system of fees established by AEC. The Commission has ample authority to provide nuclear-related consultation to requesters. The provision of non-nuclear consultation is permitted only when the service acts to provide "effective" technology transfer, and when it is not readily available from private sources.

Work for Private Industry. To meet its own program needs, AEC has established certain facilities which are unique. AEC's policy as expressed in Immediate Action Directive No. 7600-2, September 14, 1964, encourages the use of these unique capabilities by private industry insofar as:

It would not adversely affect AEC's programmatic work.

It would be conducted on a nondiscriminatory basis.

It would be provided on a full cost recovery basis wherever practicable.

It would act to provide "effective" technology transfer.

It would apply only with respect to AEC's unique or special capability.

The last condition must be met in order for AEC to comply with Bureau of the Budget Bulletin No. 60-2, which sets the government's overall policy of not being in competition with private industry.

To date, AEC has only performed a limited amount of work for private industry--and that in the nuclear area.

Access Permit Program. Since 1954 the AEC, under its Access Permit Program, has made available classified information to individuals and companies engaged in the civilian use of atomic energy. This is accomplished through plant tours, briefings, and the furnishing of reports and drawings. At the present time there are about 550 Access Permits in effect, where in almost every case the permit holder must bear the costs of obtaining security clearances.

Vendor Subcontracts. The vendor-buyer relationship is an excellent means of technology transfer. To begin with, the circulation of requests for bids informs manufacturers of changing requirements. Although the direct know-how is transferred to the successful bidder, there is usually an appreciable gain in the state-of-the-art for the entire industry.

News Releases. News releases by AEC and its contractors are an important method of information dissemination. While they do not contain detailed technology, they are useful to highlight the existence of new developments and to provide references for further contact.

Patent Policy. The AEC's patent policy is to ensure that atomic energy technology developed with public funds is made available freely to all U.S. citizens.

NASA Office of Technology Utilization

The Space Act of 1958 charged NASA with the obligation to "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

In response, NASA has evolved a program, under an Assistant Administrator for Technology Utilization, to identify new technology resulting from the agency's broad ranging R&D programs, to report it (where practical) in industrial terminology, and to communicate it to organizations in the civilian economy through several mechanisms, including regional dissemination centers.

The NASA Technology Utilization Program is organized into three major activities: (1) the Scientific and Technical Information Division, which collects (on a worldwide basis), abstracts, indexes, and brings under bibliographic control literature (published and unpublished) relating to aerospace activities.

Thus the information bank available for the NASA technology utilization effort is broader than the results of NASA research and development alone. Percentagewise, the origin of reports (unpublished documents) in the NASA system is made up as follows:

NASA and its contractors		21%
Defense Department and its contractors		30%
Other U.S. Government Agencies		6%
Other U.S. sources		12%
USSR and Soviet Bloc sources		19%
Other Foreign Sources		12%
France	1.92%	
Germany	1.58%	
Britain	1.13%	
Italy	1.11%	
26 other countries	5.93%	

Percentagewise, the origin of published documents contained in the NASA system (announced in International Aerospace Abstracts) is made up as follows:

United States	58%
USSR	15%
Britain	10%
France	3%
Germany	3%
Japan	2%
27 other countries	9%

The technical information collection now totals about 200,000 documents--and is increasing at the rate of about 5,000 items per month.

At the same time that incoming reports are being processed for announcement, a copy of each report is microfilmed (on microfiche) by the NASA Scientific and Technical Information Division (STID). This permits the contents of 1,000 reports of average size to be contained in a shoebox.

The reports are indexed in great depth on magnetic tape to permit literature searching by computer. The tapes are updated twice monthly.

That permits retrospective searching (from a variety of viewpoints) and also forms the basis of the NASA Selective Dissemination of Information Program (SDI). This is a computer-based system for notifying individual scientists and engineers of new reports and journal articles of value in their particular work. SDI can be likened to a library run in reverse: a library in which people (i.e., their specifically defined interests) are cataloged as well as acquisitions. Then, as new reports are received, they are matched against the interests of individual users.

STID is currently beginning an experimental program to examine the feasibility of giving scientists and engineers remote access to the computerized information bank--to permit them to "browse" and search as they desire on a time sharing basis--via remote consoles connected to the central computer.

The resource provided by STID becomes one of the primary bases from which NASA's Technology Utilization Program operates.

The other base is the Technology Utilization Division's activities. This division's major program elements are: (a) identification of industrially relevant new technology, (b) evaluation of that technology to determine its significance and import, (c) publication of especially useful new information in industrially-oriented language and format, and (d) dissemination of the information via regionally deployed contracting organizations (universities and research institutes) who match the new technology to the needs, interests, and objectives of organizations in their regions.

The identification function is performed primarily by Technology Utilization Officers located at NASA field centers. These personnel have the responsibility to monitor NASA research and development work at the centers and in contractor organizations to identify useful new technology resulting therefrom. When important new technology is identified, it is reported in the form of a "flash sheet" which describes the innovation in considerable detail and suggests potential non-space applications for it.

The "flash sheets" are then sent to research institutes under contract to NASA where the reported innovations are evaluated to determine their significance, novelty, and industrial relevance.

Those innovations that pass the screening in the research institutes are then published, in one of two formats: (a) as Tech Briefs, two-page bulletins, or (b) as Technology Utilization Reports, lengthier documents covering in detail those innovations deemed especially significant and useful for secondary purposes. (Approximately 150 industrial inquiries are generated, on the average, by each Tech Brief.)

In addition, the NASA Technology Utilization Division publishes new technology information in three other formats: (a) Technology Utilization Notes--collections of groups of innovations in a given field, such as <u>Selected Welding Tips</u>; (b) Technology Surveys--state-of-the-art reports on aerospace contributions to entire areas of technology, in those cases where the space program has brought about a significant increase in the available knowledge in a given area. Examples of Surveys published thus far include Advanced Valve Technology, Inorganic Coatings, Plasma Jet Technology, and Hazardous Materials Handling. These Surveys are prepared under contract by authorities in the fields to be covered; (c) Special Publications--handbooks, conference proceedings, special studies, and selected bibliographies.

The primary means* of communication of new technology to interested parties outside the space/defense community is through eight experimental regional dissemination center programs.

The reason for use of these special coupling mechanisms, at the local level, is the shared belief that publication alone will not bring about the optimum amount of technology transfer.

Each of the regional programs is also established on an experimental basis to afford an opportunity to learn how best to accomplish the transfer or channeling function.

The eight existing centers and the dates they were established are as follows:

Midwest Research Institute (ASTRA)	Jan., 1962
Indiana University (ARAC)	Jan., 1963
Wayne State University (CAST)	Jan., 1964
University of Maryland	Apr., 1964
University of Pittsburgh (KASC)	May, 1964
North Carolina Science and Technology Research Center	June, 1964
Southeastern State College (TUSC)	Feb., 1964
University of New Mexico (TAC)	May, 1965

*Normal channels, such as the Government Printing Office, the Clearinghouse for Scientific and Technical Information, and announcement to trade publications, are also employed.

Each center offers a variety of services to private companies or other organizations in their regions. Among the services:

. Application Engineering. Professional personnel in the regional dissemination centers (RDC's) help company technical people define their problems and objectives.

. Retrospective Searching. Each RDC either has a computer or obtains computer service from another RDC. A corporate engineer with a problem or objective can then pose his question to the RDC, whose personnel will devise a search strategy and conduct a retrospective literature search via computer to seek information of relevance to the question posed.

. Selective Dissemination. Each RDC builds an interest profile for each of its "customers." This is a description of that person's (or organization's) continuing interest in the form of descriptive terms that match the descriptors used to categorize information in the NASA technical information system. Then, as each new computer tape containing references to the latest NASA technical information is made available to the RDC, the interest profiles can be matched against the descriptors on the tape and a set of references (with abstracts) will be called out by the computer for each person being served. This provides a means of continuously updating a technical person in his fields of professional interest.

. Other Services. RDC professional personnel also perform other tasks to bring about the coupling of new technology and potential new application. For example, most of the RDC's conduct occasional conferences and seminars, at which companies in their regions are brought into personal contact with scientists and engineers working on the leading edge of technology (in NASA centers, NASA contractor organizations, and elsewhere). The RDC's also perform a referral function, leading customer companies to sources of additional information and to individuals in NASA who can provide them with information in depth in a specific field where the customer has a demonstrated requirement for additional knowledge. For example, if as a result of a selective mailing of information, a company became interested in exploring the feasibility of adapting a new device and producing it for sale, the RDC might put that company's technical people in direct contact with the NASA scientist who conceived the original innovation that the company seeks to modify for commercial use.

The dissemination portion of the NASA Technology Utilization Program is designed to eventually be self-sustaining (via users' payment of fees for services rendered). Three of the RDC's have initiated annual membership fees. Membership fees range (based on company size, volume of service rendered, and other factors) from less than $500 per year to more than $15,000 per year. More than 120 companies are now paying annual membership fees at three centers. More than 100 additional companies have paid for services rendered at other centers in the form of fees for seminar attendance, payment for individual literature searches, and the like. More than 3,000 companies are receiving some measure of service from the centers.

The following table gives some other measures of the NASA Technology Utilization Program:

	FY 63	FY 64	FY 65	FY 66
Flash Sheets Processed	760(1)	467	901	1,500(2)
Tech Briefs Published	0	123	300	600(3)
T.U. Special Publications Published	0	9	11	40(4)
Active RDC's	3	7	8	10

(1) The high Flash Sheet figure here is due to the first response of the NASA Field Centers to a call for past innovations.

(2) Projected on basis of first quarter, FY 66, processing and expected input from expanded contractor reporting.

(3) Based on Flash Sheet projection.

(4) Projected on basis of first quarter, FY 66, production of publications and work in process.

Clearinghouse for Federal Scientific and Technical Information

Located within the National Bureau of Standards in the Department of Commerce, the Clearinghouse is primarily a document sales agency, but also performs other information dissemination functions.

It was established in answer to a recommendation, in 1964, by the Federal Council for Science and Technology, that the Commerce Department expand its clearinghouse functions, building upon the Office of Technical Services, then in existence.

The Clearinghouse makes available, at low cost, copies of unclassified and unlimited R&D documents resulting from the work of many government agencies.

In March, 1964, the Clearinghouse assumed the function of processing unclassified documents produced by the Department of Defense.

The principal services of the Clearinghouse are the following:

(1) Sale of reports (more than 50,000 a year) based on government-sponsored R&D and sale of translations of foreign scientific and technical literature. Reports are sold in two forms: hard copy and microfiche.

The availability of new documents is announced in several ways: (a) Via mention (and abstracting) in "Fast Announcements," a new release type of sheet indicating the availability of significant new documents and grouped by subject fields. In this way, an industrialist interested in new information in the plastics field can be placed on a mailing list to obtain all "Fast Announcements" in plastics. Likewise for more than 50 other broad categories. (b) Via announcement in one of the accepted announcement journals, which include U. S. Government Research Reports, containing listings of documents generated by agencies except NASA and AEC; Nuclear Science Abstracts, listing nuclear science documents and publications; Scientific and Technical Aerospace Reports (STAR), listing new reports of the aerospace community; and Technical Translations, listing new translations of important publications originally issued in foreign languages. Recently, the Clearinghouse has begun issuing a Government-Wide Index, a monthly consolidated index to government-sponsored R&D documented results.

(2) Literature searching services are offered by the Clearinghouse. These services have recently been broadened. The Clearinghouse reports on its newly expanded service as follows: The collections that are searched include unclassified and unlimited research reports on defense, atomic energy, space and other agency projects, as well as technical translations and information on Government-owned patents.

The service is operated by the Clearinghouse in cooperation with the Department of Agriculture, the Department of the Interior, and the Science and Technology Division of the Library of Congress. The program provides a fast and economical method by which a large segment of the public with needs for research information can tap these four major Government resources. It offers "tailor-made" bibliographies suited to the requirements of scientists, engineers, and technical administrators.

The Clearinghouse reports that steps are being taken to make available under this program the literature resources and specialized information services of other Government agencies as well.

Subscribers to this service can request that a literature search be made by the Library of Congress, the Department of the Interior, the Department of Agriculture, or the Clearinghouse, or any combination thereof. If desired, a literature search can be performed by all four agencies simultaneously.

The Science and Technology Division of the Library of Congress covers the published literature of the science and technology collection at the Library. The Clearinghouse, acting as an agent, arranges for searches of the science and technology collections at the Departments of Agriculture and Interior. In addition, the Clearinghouse searches its own collection of reports derived from Government-sponsored research and development.

The flexibility of the service accommodates searching in individual subjects or in broadly related fields. The Clearinghouse collection itself has more than 350,000 documents.

The literature searching service provides two kinds of bibliographies: (a) "Current Awareness" bibliographies for keeping subscribers abreast of new developments in their fields of interest on a periodic basis, and (b) Retrospective bibliographic searches listing literature available on a subject at the time a request is made. For the"current awareness" service, the subscriber outlines the generic and specific subject fields in which he is interested. He will then receive references to pertinent materials at intervals prescribed on the subscription form (one month, three months, etc.).

(3) A referral function is also performed by the Clearinghouse, which is setting up a master file of sources of information in the physical sciences and engineering. These sources include both Government-sponsored centers and private industry. Inquirers are referred the sources most likely to have the information needed on a given subject. The Clearinghouse cooperates with the National Referral Center (Library of Congress) in providing the service.

(4) Selective bibliographies are also compiled in many areas of broad interest, such as plastics, welding, transistors, lasers, etc. By writing to the Clearinghouse for Federal Scientific and Technical Information, a free list of these bibliographies can be obtained.

(5) Technical information contained in selected Government research reports is examined, reviewed, and is "packaged" for industry's use. The resulting packages are distributed to local groups, such as universities, technical assistance organizations, state and regional economic agencies, professional technical consultants, and others. The packages consist of selected abstracts, indexes, literature reviews, and other information aimed at specific industrial needs - e.g., metal working, textiles, chemical processing.

An indication of the range of federal sources for new technology is indicated by this Clearinghouse listing of the number of reports from each agency listed in the Clearinghouse section of U. S. Government Research and Development Reports during fiscal year 1965:

Agency	Number of Reports
Atomic Energy Commission	479 (1)
Commerce Department	
Coast and Geodetic Survey	65
Clearinghouse	18
National Bureau of Standards	1
National Bureau of Standards/IAT	16
Office of the Undersecretary for Transportation	11
Patent Office	14 (2)
Public Roads	1
Maritime Administration	37
Weather Bureau	43
Department of Defense	3
Air Force	415
Army	347
ARPA	7
Defense Documentation Center	4
Navy	380

Agency	Number of Reports
Federal Aviation Agency	6
Federal Communications Commission	68
Federal Council for Science and Technology	2
Health, Education & Welfare Department	
Public Health Service	7
National Institutes of Health	1
National Library of Medicine	2
Interior Department	
Bureau of Reclamation	1
Office of Coal Research	12
Office of Saline Water	32
Labor Department	1
Library of Congress	2
National Aeronautics and Space Administration	183 (1)
National Academy of Sciences - National Research Council	22
National Science Foundation	159
Non-Government	286
Office of Civil Defense	4
Office of Scientific Research & Development	20
PAL	7

Agency	Number of Reports
State Department	1
Treasury Department Coast Guard	1
Veterans Administration	2

(1) Reports of these agencies are announced in their own announcement journals, thus few appear in this listing.

(2) Plus 1,022 patents announced.

The Clearinghouse now has 4,000 subscribers to its bibliographies. Around 80 per cent are reportedly from large companies. Often, one company represents a dozen or more subscribers. For example, one large midwestern firm has 119 people subscribing to the bibliographies.

The "Fast Announcements" are presently mailed to 20,000 people. Local groups--state chambers of commerce, manufacturers' associations, consulting engineering groups, and others--cosponsored initial meetings with field offices of the Department of Commerce to explain this program and encourage industry use of it.

The Office of Technical Resources in the National Bureau of Standards--which prepares the "Fast Announcements," and the "Packages"--reports 30 of the "Packages" have been completed to date and 35,000 copies have been distributed to requesters.

State Technical Services Program (Commerce Department)

The newest federal service in the technology transfer realm is based on legislative authority only two months old. So, of course, the program will not reach operational status for some time.

This is the State Technical Services program, established by Public Law 89-182, which calls for the development of institutions, in the states, to disseminate technical information and otherwise assist local business and industry to obtain and make use of scientific and technical information emanating from federally funded research and development.

To date, the governors of 37 states plus Puerto Rico have designated institutions to carry forward the proposed services within their states.

The purpose of the program is broadly stated in the enabling legislation as providing "a national program of incentives and support for the several states individually and in cooperation with each other in their establishing and maintaining state and interstate technical service programs designed to achieve the ends" of wider diffusion and more effective application of science and technology in business, commerce, and industry.

The technical services to be provided by the state institutions, under the program, are classified as (1) preparing and disseminating technical reports, abstracts, computer tapes, microfilm, reviews, and similar scientific or engineering information, including the establishment of state or interstate technical information centers for this purpose; (2) providing a reference service to identify sources of engineering and other scientific expertise; and (3) sponsoring industrial workshops, seminars, training programs, extension courses, demonstrations, and field visits designed to encourage the more effective application of scientific and engineering information.

The initial step under the program, as called for in the enabling legislation, is the preparation of a plan and development of a means of implementing it. Specifically, the legislation states:

"The designated agency (organization within each state appointed to administer the program by the governor of the state) shall prepare and submit to the Secretary (of

Commerce) in accordance with such regulations as he may publish: (a) A five-year plan which may be revised annually and which shall: (1) outline the technological and economic conditions of the state, taking into account its region, business, commerce, and its industrial potential and identify the major regional and industrial problems; (2) identify the general approaches and methods to be used in the solution of these problems and outline the means for measuring the impact of such assistance on the state or regional economy; and (3) explain the methods to be used in administering and coordinating the technical services program. (b) An annual technical services program which shall (1) identify specific methods, which may include contracts, for accomplishing particular goals and outline the likely impact of these methods in terms of the five-year plan; (2) contain a detailed budget, together with procedures for adequate fiscal control, fund accounting, and auditing, to assure proper disbursement for funds paid to the state under this Act; and (3) indicate the specific responsibilities assigned to each participating institution in the state.

This program, then, is designed to provide local access to information generated by federal R&D programs of an unclassified and unlimited nature. It will not permit special tailoring of the information to the specific needs of the individual user, however, because the law states that no services may be specifically related to a particular company, public work, or other capital project except insofar as the services are of general concern to the industry and commerce of the community, state, or region.

Office of Science Information Service, National Science Foundation

While this organization does not operate a technology transfer program, it is mentioned in this context because it has several significant tasks to perform in the development of more effective information dissemination mechanisms.

Title IX of the National Defense Education Act of 1958 directed the National Science Foundation to "provide or arrange for the provision of, indexing, abstracting, translating, and other services leading to a more effective dissemination of scientific information" and to "undertake programs to develop new or improved methods, including mechanized systems, for making scientific information available." Under this directive, the NSF Office of Science Information Service (OSIS) was established, replacing the former NSF Office of Scientific Information.

The primary role of OSIS, then, is one of coordination, supplementing, and research for the improvement of scientific information systems, rather than having an operational nature.

The organizational chart for OSIS--reproduced as the following page in this paper--indicates the scope of the organization's functions.

Work performed by the Studies and Support Section of OSIS represents, in many cases, a contribution to the ability of other organizations--public and private--to improve their systems for the handling and communication and scientific and technical information.

For that reason, it is appropriate to report the scope of activities within the Studies and Support Section in some detail in this paper. These activities are outlined well in an NSF publication, "Improving the Dissemination of Scientific Information." Following are excerpts from that publication that report on the scope of activities of the Studies and Support Section of OSIS...

Research and development directed toward systematic and, where possible, mechanized procedures for handling large volumes of scientific information have been supported by the Foundation for a number of years. The objective of the Information Systems Program is to continue this research

OFFICE OF HEAD

Directs and coordinates the planning, development and execution of programs and activities assigned to OSIS:

1. To foster the interchange of scientific information among scientists in the United States and foreign countries. (Reference: NSF Act of 1950, as amended)

2. To provide, or arrange for the provision of, indexing, abstracting, translating, and other services leading to a more effective dissemination of scientific information and undertake programs to develop new or improved methods, including mechanized systems, for making scientific information available. (Reference: Title IX of National Defense Education Act of 1958)

3. To provide leadership in effecting cooperation and coordination among non-Federal scientific and technical information services and organizations, and in developing adequate relationships between Federal and non-Federal scientific information activities. (Reference: OST letter of February 29, 1964)

STUDIES AND SUPPORT SECTION

Plans, develops and directs programs and activities for basic science information studies, improved information handling methods and systems, and support of science communication.

RESEARCH AND STUDIES PROGRAM

Activities aimed at developing new knowledge on (1) communication practices and the flow of information in the sciences, (2) the effectiveness of information sources and services, and (3) techniques for information organization and searching.

INFORMATION SYSTEMS PROGRAM

Activities aimed at development of improved systems for processing scientific information, especially through experimental application of existing knowledge, techniques, and equipment to scientific information problems.

PUBLICATIONS SUPPORT PROGRAM

Activities aimed at increasing the availability of scientific literature through temporary support of primary and secondary scientific publications and the translation of significant foreign scientific literature, primarily Russian, Chinese and Japanese.

SCIENCE INFORMATION COORDINATION SECTION

Plans, develops and directs programs designed to provide leadership in effecting coordination and cooperation among non-Federal, and between Federal and non-Federal science information activities and organizations. Provides liaison with other Federal information activities.

DATA COLLECTION AND PUBLICATIONS UNIT

Grants and contracts for data collection and OSIS publications on science information. Special projects. Distribution of OSIS grant and contract reports, and publications. Scientific Information Notes. SIC Secretariat.

DOMESTIC AND FOREIGN SCIENCE INFORMATION PROGRAM

Activities leading to improvements in science information activities in the non-Federal sector, including foreign and international, with emphasis on the role of scientific societies and organizations.

FEDERAL SCIENCE INFORMATION PROGRAM

Programs and projects which relate the flow of the Government's science information activities to the needs of the private and academic science communities.

National Science Foundation
Office of Science Information Service
September 1964

and development and to extend it through the application of existing knowledge, techniques, and equipment to the design of improved information systems. Work in this area frequently requires the combined talents of many kinds of specialists including linguists, mathematicians, logicians, computer experts, librarians, and information specialists. Support is provided for research, development, experimental applications, and evaluation of systems in the areas of information retrieval, mechanical translation, libraries, and publications. Principal emphasis is on improving the basic understanding of generalized problems rather than on establishing particular systems.

Recent years have seen the development of a number of mechanized or mechanizable methods for organizing and storing information. Differing widely in the way that the subject content of documents is determined and represented, many of these methods have certain undesirable limitations stemming from a generally insufficient knowledge of language as the mode of expressing thought. To help overcome this lack of knowledge, the Foundation continues to support long-range research on systems for the automatic processing of natural-language text, with the eventual aim of mechanizing procedures for indexing, abstracting, organizing, and storing information.

While new knowledge, techniques, and information-handling equipment continue to be developed, little effort has been devoted to their experimental application in a system environment to evaluate total system performance. A principal objective of the Information Systems Program in this area is to develop and evaluate experimental information retrieval systems. Such experimentation includes consideration of the user, the study and improvement of man-machine-environment interaction, the investigation and analysis of system networks, and the development of evaluation tools.

A second major interest of the Information Systems Program is mechanical translation. Research in mechanical translation is part of the broader field of automatic language processing, and like the field as a whole it is marked by gradual progress in gaining an understanding of the problems involved and in gathering the necessary language data. The projects supported by NSF are designed to provide a better understanding of language and of the basic problems of translation, and to develop workable, automatic procedures for translating. Although the primary goal of research in this field is the automatic production of translations from one language to another, the investigations are expected to contribute significantly to the development of procedures for automatic linguistic analysis for other purposes, such as mechanized indexing, abstracting, and literature searching. The Foundation has a continuing interest in: man-machine translation systems which take advantage of present capability for automatic language processing; more powerful computer programs capable of automatically carrying out a variety of language processing tasks; automatic lexicography both as a prerequisite and as a by-product of progress in mechanical translation; and the problem of evaluation of translation quality.

A number of new printing techniques, including computer-controlled photo-composition and printing, have been developed over the past several years. The analysis of present publication systems and networks is considered prerequisite to the development of improved systems which utilize new techniques and machines. Projects have been undertaken for the analysis of the role of the computer in scientific publication and for a study of machine recording of textual information during the publication of scientific journals.

As a part of the Foundation's general program for strengthening the science library network of the country, the Information Systems Program is seeking ways to improve the effectiveness of those libraries providing substantial science information services. Of particular interest are studies leading to a greater understanding of libraries, involving systems analysis and related techniques for determining the functional design of libraries and interlibrary networks and the economic feasibility of mechanization.

The Publications Support Program helps increase the availability and utility of science information in the mathematical, physical, engineering, biological, and social sciences through support of: (1) primary journals, monographs, and conference proceedings; (2) abstracting and indexing services; and (3) foreign translations.

Foundation support of scientific abstracting and indexing services is made to assist with the establishment of new services, to help existing services through financial emergencies, or to enable them to accomplish specific publishing tasks that will improve their usefulness; typical tasks include expansion of subject coverage, elimination of backlogs, and issuance of cumulative indexes.

The broad concern of the Research and Studies Program is the stimulation and support of research on information problems. The program's major objectives are as follows:

1. To learn more about the ways in which scientists and engineers communicate information to each other.

2. To evaluate the effectiveness of scientific information sources and services.

3. To develop improved information-handling techniques that will result in more useful and economical scientific information services.

The Foundation studies communication processes and patterns in science in order to evaluate and improve information services. Data on the information practices of psychologists, physicists, chemists, biologists, and engineers are gathered and analyzed. OSIS supports studies with the following objectives: the gathering of descriptive data, where needed, on the way scientists and engineers communicate and use information; the development of models of communication processes in science; analysis of the functions served by information and information services; and the development of methods and criteria for evaluating the utility of information services to their users.

To assess the adequacy of existing scientific information services, there is a need for a continuing analysis of the characteristics, quantity, and rate of growth of the world's scientific literature, and also of the characteristics of the information services now available. To meet this need, the Foundation supports studies and statistical analyses of the literature and of the coverage of secondary publications and information services. It supports experiments with new kinds of indexes and studies of their use. Support is provided also for experiments to determine the effectiveness of new means of publishing or disseminating the results of research.

As part of the larger problem of dissemination of scientific information, the Foundation is interested in the development of improved methods for organizing and searching very large information or document files. The basic objectives of the Research and Studies Program in this area are: improved understanding of information organization and searching processes; the development of methods and criteria for evaluating such processes; and the development of new and more effective procedures, mechanized wherever mechanization proves to be advantageous.

Some work has been done on the theoretical bases of information organizing and searching. Some test methods for evaluating the performance of indexing procedures have been developed and tried experimentally on operating systems, and exploratory studies of evaluation criteria have been made.

Other research has been concerned with the development of more systematic procedures for subject analysis, indexing, and searching; automatic techniques for grouping related concepts and for assigning documents to the resulting classes or categories; automatic analysis and indexing of abstracts of scientific documents; and procedures for the organization of very large files of information.

Some Proposed Mechanisms

We have seen that the application of technology to needs and objectives in the civilian economy can result in important economic, social, and cultural benefits.

We have also seen that a huge--and rapidly growing--inventory of scientific knowledge and technological capability exists in the U.S. as a result of continuing high public investment in research, development, and engineering.

We have found that reliance upon traditional processes for the diffusion of science and technology results in undesirable lags in the application of that knowledge and capability in contexts outside the military/space realm.

We have seen that it is possible to catalyze the transfer process. Existing experimental programs have been successful in bringing about some transfer--and have provided an opportunity for learning. But we still have much more to learn if we are to effectively create a catalytic effect.

It appears that our ability to bring about technical innovation has outrun our capability for social invention at least momentarily. "It is a fair comment that industrial societies have shown little originality or ingenuity in creating institutions to ensure that all new ideas will be swept into the net and that nothing will be lost."[99]

In recent years--when, at last, noteworthy scholarly attention has been paid to the question of technology transfer--it has become increasingly apparent that new mechanisms must be devised to perform the transfer or channeling function.

It is now recognized that, "in a society as complex as ours, it would be sheer coincidence if the producer of new knowledge or ability should meet with the potential user.

99. The Sources of Invention, op. cit., p. 9.

We need intermediaries, variously described as innovators, merchandizers, advocates, couplers, entrepreneurs. No matter what they are called, it is they who must match the potential of scientific knowledge gained through research; the production capability resulting from engineering development of research results; the physical needs and wants of society as interpreted by marketing research and analysis; and the cultural values of this society as reflected by economic, social, and political attitudes and activities. Without them, there will be haphazard match at best between the means and ends."[100]

What is being demanded are mechanisms that will take the technology to the potential user rather than to hope that the potential user might seek out or stumble across the technology. That implies the making available of relevant and accurate information to the potential user in a language and form that he understands, at the time when it is useful to him, in an environment conducive to his acceptance of it.

Certainly, a competitive free enterprise system works in favor of the application of new technology. The pressures of the marketplace spur the innovative process. As one spokesman has noted: "In today's economy, if you can't say your product is 'new and improved,' you had better be ready to say '20 per cent off.'"[101]

But motivation and desire are not sufficient conditions for solution of the problem. The desire to keep from drowning doesn't always teach a man to swim.

In an earlier time--when the technology was less complex and less voluminous--the technically trained entrepreneur was able to seek out the information he needed. That capability diminishes with each passing day.

The impact of a technological advance is like a pebble dropped into a pool. The ripples spread out. But today, the

100. Schrier, op. cit.

101. Gadberry, op. cit.

pebbles are raining into the pool. The ripples are buckling against one another, overlapping one another, joining forces to become larger ripples, creating by their forces and dynamic movement new ripples under the surface that break forth to the surface and eradicate other ripples while they are still forming.[102]

The pace of technological change...the volume of new technology being generated...the multidisciplinary impact of technology...the multiplicity of diverse uses for new knowledge--these conditions create a need for social invention. Doing less leaves us in a defensive rather than an offensive posture in relation to change.

The unmet human and community needs with which we are most concerned today have one common element: their solution, in a technological sense, will be largely dependent on the ability of private companies to muster all of the required technology and apply it in a highly specific fashion.

No one doubts the ability of existing corporations to design systems to solve many of the problems. But will those be the optimum systems? Not unless all the reasonable alternatives can be examined. Provision must be made to do so.

The development of a desirable mass transit system depends, in the end, on an ability to make the best bearings and seals; the best, low cost, automatic control systems; the most efficient air conditioning equipment; the most effective sound and vibration damping; and other related hardware items.

Thus the ability to channel new technologies to technical people in private companies must be the central objective of any effective technology transfer program. As Sumner Myers noted:[103] "An invention might be conceived in or out of a business firm. It may be perfected in or out of a business firm. But, sooner or later, if it is to be introduced into the economy, this will be done through a business firm."

102. Howick, George J., "Technology's Impact In The Marketplace," Speech at Quarterly Conference of Technoeconomic Trends, New York, September 16, 1965.

103. Myers, Sumner, "Attitude And Innovation," International Science and Technology, October 1965.

Perhaps social invention is required on two planes: one, to get new technology to those private companies who can apply it--both as a means of speeding economic growth and as an essential element in the solution of public problems--via a system responsive to the needs of individuals in the technical community; and two, to aid, from a systems viewpoint, in creating the means (or an effective market) for applying new solutions to our problems.

For example, the many technological inputs useful in the design of better air pollution control devices need to be channeled to private companies serving that market. And, secondly, a means must be devised to bring together all of the fragmentary influences who will determine whether new control methods are indeed put to use.

To effectively solve the air pollution problem[104] in any metropolitan area demands the cooperation of civil authority of the many municipalities, counties, and other political subdivisions that make up that metropolitan area. In some cases (the New York, Kansas City, and Cincinnati areas, for example), more than one state is involved. Or consider the question of solving the water pollution problem in Lake Erie and making maximum use of that natural resource--where you must involve two countries, eight states, and uncounted local governmental bodies.

The greatest motivation for the use of new technology is the existence of a market to which it can be applied. But how can private industry be expected to make huge investments in the engineering effort required to convert new technological knowledge into practical hardware when there is not the least assurance that the resulting devices can be sold at a profit? Thus, there arises an apparent need for social innovation at the market level.

Some entrepreneurial efforts of this type have been accomplished. One good example is the School Construction Systems Development project in California (see Appendix J).

104. Or mass transit, water pollution, crime prevention, waste disposal, or numerous other issues.

In that case, advanced building design concepts are being applied because several school districts indicated a willingness to buy the resulting product. The entrepreneurs involved created a market of sufficient size to justify the investment--by several private companies--in the engineering of advanced building components and subsystems.

It must be remembered that technology does not occur in readily useable packages. To solve a specific problem in one context may demand the pulling together of technology developed for a dozen other purposes, its adaptation to the specific situation (at considerable cost), plus--often--the invention of additional technology.

Making effective use of new technology often requires more investment--and more creative ability--than did the creation of that technology in the first place.

The competitive market is an exceptionally fine mechanism for bringing about that investment and that application of ingenuity.

But the marketplace has not been able to function effectively in relation to the pressing urban problems of today. The influences that would create a market are so fragmented that no market has been shaped or defined.

Where a problem exists, there generally is economic opportunity. Where there is economic opportunity, private business should be capable of response. But in the case of most urban problems, there is a missing link--a definable, responsible consumer.

Perhaps a related reason why these problems have not been solved is because a highly sophisticated systems approach must be employed. The factors to be considered are many--and in dynamic relationship. The systems capability required exists in few places outside the space/military sphere.

That kind of reasoning stands behind the experimental programs underway in California where large private companies--accustomed to working on space/military problems--have been asked to consider questions like the control of crime and delinquency.

When the State of California decided to sponsor four studies of such earthly problems, more than 50 companies--mostly from aerospace--competed for the four $100,000 contracts. Each winning company has reportedly spent more than twice that amount in consideration of the problem. That indicates the responsiveness of private industry to the existence of a market.

Our problem, it seems, is that we have not been able to convert our unmet human and community needs into definable markets that would be recognized economic opportunities.

Senator Nelson has recently proposed studies similar to those in California on a national scale (Senate Bill Number 2662). In introducing the proposed legislation, Senator Nelson noted, in part: "It would be highly in the national interest to begin devoting a portion of the talents and brains of our defense and space industries to other national goals of a great society. This would require no diminution in either our defense or space commitments. We can do both--we can have guns and butter; we can have a moon shot and a national plan for the abatement of pollution; the Polaris project is not incompatible with a new and scientific attack on the terrors of crime. Moreover, the California studies have shown that private firms can help us achieve this objective...

"In fact this capability and brain power already available throughout the nation is...a scientific weapon of demonstrated power and a source which represents a huge national investment.

"Our task is to recognize that we have the scientific know-how, and the men, to solve almost any problem facing society. Once we understand this, I am confident we will choose to use the resource; we will choose to set our highly-trained manpower loose not only on space probes but on down-to-earth problems; we will choose to use systems analysis, the computer, and every modern resource available to us in the quest for progress."

A possible means of using those resources and at the same time bringing together the fragmentary influences for the solution of urban problems was suggested at the Engineering Foundation Research Conference on "Technology and Its Social Consequences," held at Andover, New Hampshire, July 26-30, 1965.[105]

The suggestion involves local competitions for government grants to design systems solutions to urban problems. Patterned in part after the Atomic Energy Commission's request for proposals on the location of its proposed new linear accelerator, the suggestion would be for the Federal Government to offer a sizable grant--or matching funds--to the winner or winners of a competition for the design of systems for mass transportation, waste disposal, and other urban problems. Proposals would be submitted by and on behalf of entire communities.

The demonstration system that would likely be designed by the winning community, with federal support, would be adaptable to the needs of other communities.

The value of this proposed mechanism lies largely in the ability of such a potential award to create a recognizable market--to act as a means of drawing together all the groups within a community who will influence the solutions to that community's problems. Thus it is felt that much will be gained even by those communities that do not win awards--because many diverse interests in those communities will have worked together to design proposals. That cooperative effort is seen as a stimulus to further cooperative efforts. In other words, such a grant program would tend to achieve a degree of cohesiveness and cooperation in many communities that theretofore would not have existed. In part, it is the use of the systems concept in a social and political as well as technological sense.

105. Credit for the suggestion must go primarily to Dr. Lyle C. Fitch, President, Institute for Public Administration, and Dr. Arthur Weimer of Indiana University.

There is no doubt that a systems approach is required for the solution of most of the pressing problems of our urban communities. As a result, it is frequently suggested that solving these problems might come about through encouragement of companies now serving the space/military market to diversify into the areas where the major problems lie. The California experiment tends to reinforce that view.

Whether such diversification would be the optimum approach to solving the problem is debatable. The record of successful diversification by defense contractors is meager. Murray Weidenbaum[106] has pointed out: "Since the end of World War II many major defense contractors have sought to diversify their operations into commercial lines of business...These companies attempted to utilize the technological capabilities developed in the course of their military work to design and produce a great variety of commercial items...With one major exception, these diversification attempts have each been relatively small in comparison with military equipment. The exception, of course, is transport aircraft for the commercial airlines... Other than the few firms selling to the airlines, the large defense suppliers, especially in the aerospace field, have reported commercial sales of 1 or 2 percent, or even less, over the years. The list of abandoned commercial ventures is a long and constantly growing one. The surviving efforts continue generally at marginal levels--either actually losing money, barely breaking even, or showing profit results considerably below military levels.

"A variety of reasons is usually given for the inability of the large specialized defense companies to utilize their resources in commercial endeavors--their lack of marketing capability and their inability to produce large numbers of items of low unit price. These weaknesses are not necessarily handicaps in defense and space work, where other capabilities are more important."

106. Weidenbaum, Murray L., "The Transferability of Defense Industry Resources to Civilian Uses," Reprinted in <u>Convertibility of Space and Defense Resources to Civilian Needs: A Search for New Employment Potentials</u>, Report on selected readings in employment and manpower prepared for the Senate Subcommittee on Employment and Manpower, Washington, D.C., 1964.

Solo[107] has also explored this question: "Differences setting the civilian apart from the space/military forms of business organizations also appear to be growing. The two sectors have taken different paths of development. It is entirely natural that this should be so, for those who produce and sell to the civilian market and those who produce weaponry control systems, instruments, and components for the military market operate in quite different environments, and are shaped by quite different forces. Sharp variances between two sectors show up--in the nature of risk; in the appropriate ethics and standards of conduct; in the means to survival and growth; in the emphasis on the costs of production in the one instance and on performance characteristics in the other; in the fabrication of the complex, perpetually changing, prototypes in the one and in prerequisite long runs of standardized outputs in the other; in the buyer-seller relationships; and in the nature of organization controls."

The problems of defense contractor diversification into other areas of endeavor are obviously formidable. But considering the capability that exists in such corporations, their ability to contribute to the solution of civilian problems dare not be lightly dismissed.

Another means of bringing the knowledge to the need--or focusing the capability on the problem--that is frequently proposed is to encourage the mobility of technically trained people. It is suggested that the "transplantation" of sophisticated technologists and experienced systems analysts from military/space organizations to organizations serving civilian markets would raise the level of technical capability in organizations that already have the marketing knowhow to deal in the civilian sector.

Allison[108] has reported on that issue: "One of the most serious phenomena we are up against is the direction in which 'people transfer' goes: For it goes in the wrong direction--from civilian to defense. Donald Fink, ex-head of Philco's

107. Solo, Gearing Military Research and Development to Economic Growth, op. cit.

108. Allison, op. cit.

research activities, tells how it happens in the electronics fields: 'In electronics there are two groups of engineers: Those who are still working on consumer and industrial products and those who have gone on to government work. These two groups are quite distinct and the path from one type of occupation to the other is strictly a one-way path. They (scientists and engineers) do not go back because government work allows them to work near the frontier of science and technology; if they are clever and hard-working, they will use the proper engineering solution and it will be paid for.' The result of this, says Fink, is that technological advance in consumer products is at a standstill compared with weapons systems...We are developing scientists and engineers who do not know the free enterprise system, because they have only lived in the Federal Government environment."

Most of the evidence that has been gathered tends to support the conclusion that there is little movement of personnel between the two sectors. In fact, movement within the space/defense community--from one organization to another--may be greater than movement from outside the space/defense community into it.[109]

But whether or not such mobility can be brought about seems beside the point anyway. It would certainly not be proper for the government to attempt to intervene in the process by which people choose where they want to work. Nor does any other means of encouraging such mobility on a large scale seem practical.

While the lack of inter-sectoral mobility may be viewed as a problem per se, it represents what may be an even more difficult problem in the context of technology transfer, i.e., the difficulty in communicating from one sector to the other.

A message is more likely to gain understanding and response if it fits the pattern of experiences, attitudes, values, and goals that the receiver has. True communication

109. A study by NASA, in early 1965, of the origins of scientists and engineers hired by NASA from October 1, 1962, through September 30, 1964, found that 57 per cent of those hired from private industry came from 17 NASA contractors. The remainder came from 325 other companies. Total hires from industry were 1,648; 973 came from other federal agencies.

is dependent on a number of forces--and the sender of the message can really only control a few of them. He can shape his message and he can decide when and where to introduce it. He cannot control the environment in which the message is received and in which response takes place; the attitudes and personality state of the receiver; or the receiver's group relationships, standards, objectives, and priorities.

The problem has been eloquently described by Robert A. Solo:[110] "Rendering articulate the complex and the new is a most difficult task; difficult even when those who would speak together share a common language. And sharing language is far less the usual case than is ordinarily supposed. Such a language is no mere matter of grammar, syntax, and standardized vocabulary. It is also in the habits of thought, in the individual's points of reference, in his philosophy, his values, and his experience, in the form of establishing credibility, and in his manner of ordering the evidence. We speak at each other but we hardly ever converse. And if the one speaks openly and clearly of the significantly new, the other must not merely listen. He must have the capacity to comprehend and assimilate. He must be able to understand. There are two sides always, the speaking and the listening, the giving and the receiving; both require effort and skill. The communication of significantly new insights, invention, thought--even between two individuals face to face--is difficult and rare. But how infinitely more difficult when the communication of invention or discovery is not from man to man but from group to group, from company organization to company organization, from industry to industry, from sector to sector, from nation to nation, from social culture to social culture. Language, interest, outlook, distance, and time--sheath upon sheath--separate the thought and perception of one from the perception and thought of another."

The point is this: Any means of channeling new technologies in promising directions eventually boils down to communicating information on new technology from its point of origin to its points of potential use.

110. Solo, Robert A., Studies in the Anatomy of Economic Progress, A working paper.

Rosenbloom[111] has agreed: "The transfer of technology--whether it be from person to person, firm to firm, industry to industry, or government to private enterprise--depends primarily on the exchange of information rather than upon the exchange of things. In the long run, therefore the fullest utilization of the technological by-products of military and space development will flow from a healthy and effective technical information system. This system is not a single monolithic entity, but rather is an amalgum of many loosely interlocking institutions and procedures, serving many publics, concentrating on various aims. Within it, information is exchanged not only by the storage and dissemination of documents, but also by many interactions, formal and informal, between people."

Thus the mechanisms devised to perform the function will center on the gathering, evaluation, packaging, analysis, interpretation, categorizing, extrapolation, assembly, association, handling, and communication of information.

To perform those tasks well, we must learn considerably more about both man and machine. We must develop mechanical and electronic tools--computer systems, primarily--to permit us to speed the routine portions of the task. And we must find, educate, and motivate people to perform the more imaginative portions of the work.

As has been reported in this paper, some of the experience and knowledge necessary to build these man-machine systems has already been achieved and more is being accumulated from programs now underway.

An examination of history also shows that we have numerous models from which we might borrow--and some of which we might want to deliberately duplicate, experimentally, to learn how to design ultimate systems.

Dr. Donald Schon has referred to these models[112] as the library model, the teaching model, the skill model, and the new technology model.

111. Rosenbloom, op. cit.

112. Reported by Elliott Schrier in Technology and Culture, op. cit.

He notes that the first three are essentially one-way processes, with the prime requirement being communication on an explicit or implicit question. Success of the transfer mechanism is measured by how well the question is answered.

In the library model, the question usually involves specific information and the question is answered in the form of documents--not necessarily specifically tailored to answer the question.

The teaching model is more diffuse; it attempts to answer the question "why". Understanding begins to be emphasized more than documents.

The skill model involves the movement of ability rather than understanding.

The new technology model is, in Dr. Schon's words, a projective process in which the transfer is achieved in part through analogy proceeding from similar technology, in part through invention, in part through innovation, and in part through invasion by more highly developed companies or industries into underdeveloped companies and industries.

Unfortunately, says Dr. Schon, the library model has dominated all other transfer processes.

In many instances, there is a real question whether money should be spent to search for a document, to search for knowledge and skills, or to start from scratch.

Perhaps one reason that question occurs so frequently is that our models have been less than adequate--and that we have failed to combine elements of several models into one system.

We have seen that there is, increasingly, a need to provide a means of taking the technology to the potential user, rather than hoping he'll be willing and able to unearth it from its variety of resting places.

We have seen that the transfer of technology depends primarily on the effective communication of information (implying relevance of the information and understanding on the part of the potential user).

We have seen that meeting many unmet needs will depend, in large measure, on the ability of innovators in private companies to obtain a wide range of scientific and technical information in a form conducive to their use of it. That means that a focal point in the design of channeling methods must be innovators in private companies.

The next question to consider, then, is what we have learned and understand in regard to the essential elements of a system that will successfully channel new technologies from their multiple points of origin, in a variety of combinations, to their many potential points of use.

The Elements of A Transfer System

"We all take the telephone for granted. When we have to wait more than a few seconds for a dial tone, we grow impatient and frustrated. When we call information--seconds seem like hours. We also take for granted the telephone directory--that innocuous book which methodically lists names and numbers in alphabetical order. Imagine the chaos in the telephone company information centers if one day every other page in everyone's phone books were missing. Imagine your frustration if most telephone numbers were "unlisted"--if a special, prolonged, and elaborate effort was necessary each time you made a call.

"Contemplate the chaos in your city if there were hundreds of different phone books--some arranged by people's national origins, others by occupations, by district or by name--yet none of them complete. Each time you needed a phone number you would have to know whether your friend was Irish, or a janitor, or whether he lived in the north side of town. Suppose that in each city the system was different--each used a different terminology or system of spelling-- a janitor might be a superintendent or a maintenance engineer.

"Suppose each of these phone books, large and small, is only half complete and at least a year old when it arrives. Suppose that phone books were not free but cost so much that only libraries could purchase them. Imagine your frustration if you had to go to the library each time you wanted to make a phone call.

"Now what has all this to do with the so-called information crisis? The situation I have just hypothecated is a fairly accurate description of scientific communication today. There are some obvious exaggerations. On the other hand, there are even more chaotic aspects difficult to convey by simply analogy. We all use the yellow pages, the classified directory, and frequently find it difficult to locate a number because of peculiarities in our language. Gas stations are listed under service stations and sell gasoline; gas companies may be listed under power companies and sell gas. In science, terminology is constantly changing--faster than the lexicographers or dictionary publishers can cope with. Every scientific dictionary is obsolete long before it is published.

"In science communication we not only call local numbers--we are constantly trying to place long-distance transoceanic calls because science is international. Our telephone operators, the information scientists and librarians, must be able to handle dozens of languages including Japanese, Russian, and other exotic tongues.

"However, this is only the beginning of the difficulties. After painfully identifying the telephone number of the scientific document he needs, the scientist can't simply dial the number. He must first identify the telephone exchange that handles this number. He may be lucky and find that it is a local exchange. Quite frequently he will find that he must call a Washington exchange or some other remote city. But scientists are stubbornly persevering, and having learned the proper exchange, put through the call only to find that the line is busy. In fact, the average waiting time is a few weeks--and by then--if that hasn't discouraged him--he may find that he called the wrong exchange, the number is out of order, or disconnected, temporarily or permanently. It is not surprising that by the time his call does get through he has sometimes forgotten why he called in the first place.

"The working scientist places hundreds and thousands of such calls each year. He would call more often if he did not anticipate, consciously or intuitively, delay and frustration. The net result is that he gives up and only makes a call when he is absolutely desperate."[113]

That analogy from Dr. Eugene Garfield points up some of the complexities involved in the design of a national system to channel technology. It is an obviously demanding task. William T. Knox, formerly manager-corporate planning for Esso Research and Engineering Co., now in the Office of Science and Technology and chairman of COSATI, served as manager of Esso's Technical Information Division for five years. "During that time," he says, "I changed from a research director ignorant of

113. Dr. Eugene Garfield, in testimony before the Ad Hoc Subcommittee on a National Research Data Processing and Information Retrieval Center, op. cit., p. 227.

the enormous problems in the technical information field and skeptical of my interest in it to one who believes that the successful solution of the technical information problem is vital to the continued health of science and technology and demands the very highest skills and capabilities of professionally trained people."[114]

A similar change of attitude--on the part of many highly placed government officials and the top executives in corporations--will likely be required if effective technology utilization programs are to be developed.

Technology transfer--using new technology for purposes other than the specific one for which it was created--is not now given much emphasis in many government program offices. Until it is given higher priority, major problems will exist on the input side of the transfer mechanism. For locating the technology which is truly new and significant demands the cooperation of those program offices with the scientific and technical missions, and therefore the R&D budgets.

And--on the output side of the transfer mechanism--the quality of receivership must improve--meaning that the managements of private companies must be exposed to the benefits they can derive from the utilization of government-generated technology.

Between the two (input and output) must be built new bridges--not made exclusively of paper--over which the right information can be successfully conveyed. And the bridges must permit traffic in both directions.

Let's consider the steps in the transfer process, briefly, one by one. These steps are:

- Finding the technical information.

- Screening out that which has current relevance for possible special emphasis--but not abandoning what remains (for it may have unrecognized value).

114. Research Management, July, 1964, p. 287.

. Organizing it in a manner that permits its retrieval for a variety of potential users--with different languages, interests, and orientations--in a rapid and efficient manner.

. Bringing relevant parts of it, on a selective basis, to the attention of a variety of potential users.

. Arranging for seemingly unrelated pieces, originating in separated areas, to be fitted together.

. Encouraging its use, on the basis of its value.

. Relating it to ongoing efforts that may enhance its value.

. Organizing it in such a manner that it not only can be called out to meet specific defined needs--but also so that it can be a source of ideas to the technical man who will "browse"through it.

. Permit the full inventory to be examined in such a way as to allow the discovery of areas of knowledge convergency or potential breakthrough areas, and areas of need.

. And all of this must take place in an economic and social environment conducive to change.

Let's consider what is implied at each of those steps in the process...

Finding the Information

Technology exists in many forms--in documents of many kinds, in not-yet-articulated concepts and understanding, in physical devices and systems. The documents will appear in such diverse forms as patents, research reports, data not yet analyzed, handbooks, trade press articles, papers in technical journals, proceedings of conferences and seminars, scrawlings in the notebooks of scientists and engineers, and countless other forms.

The chances of finding it will not be good unless at least two conditions are met: (a) capable people are assigned, as their primary responsibility, the task of seeking it out, and (b) those who generate it--the practicing innovators and their supervisors--recognize the value of transferring the results of their work and agree to cooperate.[115]

Some pioneering efforts of this type, on a formal basis, are underway. The Science Information Exchange, for example, has elicited the effective cooperation of most segments of the government community sponsoring and conducting research in the life sciences. Those offices now bring to SIE's attention their current R&D activities. And SIE has put professional analysts to work documenting those activities--for, to be widely communicated, information must be articulated and recorded.

NASA is providing another model. Its technology utilization officers, deployed in the various NASA installations, have the primary responsibility for seeking out the important results of research and development efforts conducted in NASA centers and by NASA contractors. And NASA has put teeth in its philosophy by placing contractual responsibility on its contractors to report the new technology resulting from their work under NASA support.

The AEC has been successful in encouraging its scientists and engineers to recognize the importance of civilian applications of the nuclear technology they generate. And many economically important activities in civilian industry have thereby come about. Now the AEC is considering giving some emphasis to pinpointing the non-nuclear technical advances

115. The size of this task might be illustrated by one example, the Gemini program. McDonnell Aircraft Corporation, prime contractor for the capsule, has 3,196 subcontractors and uncounted suppliers to the subcontractors. Martin Company, responsible for the Titan II launch vehicle, has an estimated 1,500 to 1,800 companies supplying services, parts, and materials. The subcontractors range in size, for example, from General Electric Company to the Blake Rivet Company, a firm with 60 employees that made the special titanium alloy fasteners used in assembling the capsule. And the suppliers range in technology base and orientation from IBM to the David Clark Company, a brassiere and girdle manufacturer that made the space suits.

made in the course of its nuclear research and development.

The Clearinghouse for Federal Scientific and Technical Information has undertaken an effort to encourage other agencies to provide copies of their research reports to the Clearinghouse.

And the editors of trade, technical, business, and professional publications must also be recognized for their extensive contributions to the location of new technology via continued field work.

The combination of those efforts is beginning to create an environment for the recognition among innovators of the potential secondary importance of their work.

But more is required. Perhaps a national policy encouraging the reporting of new technology (of an unclassified nature) would be helpful. And perhaps there is a need to analyze and more specifically define the conditions under which limitations should be placed on the communication of unclassified information.[116] And government agencies should continue to be encouraged to declassify documents at the earliest time consistent with national defense considerations. And, ideally, all agencies generating a significant amount of new technology might be encouraged to assign responsibilities for the identification of new technology to qualified and enthustiastic personnel.

Screening the Information

With apologies to Gertrude Stein[117] (and dyed-in-the-wool documentalists), a document is not a document is not a document. The value of one piece of information is not necessarily equivalent to the value of another piece of information.

116. Of the total number of documents announced by the Defense Documentation Center in the twelve months ending July, 1965, 47 per cent were unclassified but limited; 32 per cent were unclassified and unlimited and 21 per cent were classified.

117. "A rose is a rose is a rose."

But the library has served, often, as the model for technology transfer mechanisms. The result, in many cases, is a need to wade through a considerable amount of straw in search of the wheat. And too much straw in the diet discourages eating. It also makes for a lot of wasteful mastication.

Burning the straw may not be wise; new uses for it may be found in the future. But it should not be allowed to be served as the main course.

Means are required to screen information, finding that which is of special significance and relevance, and giving it special emphasis--perhaps by calling it to the special attention of potential users.

But in the process, no information should be discarded on the basis that it appears to have no practical value at present. It should be retained and categorized in such a way that it will be retrieved for those purposes for which it might be important at some future date.

Some effort is being devoted in government to this evaluative function.

NASA, for example, employs several private research institutes to evaluate innovations reported by the NASA technology utilization officers. And those innovations deemed of special merit are given special emphasis by publication in the form of Tech Briefs and TU Reports.

The Clearinghouse, with the aid of the Office of Technical Resources, screens incoming reports to find those of special significance, then calls attention to them via "Fast Announcements."

The Atomic Energy Commission holds conferences and undertakes programs to encourage the use of especially significant items, such as its liquid zonal centrifuge.

But only a relatively small portion of the new technology generated through government R&D programs is evaluated for transfer purposes.

Certainly, some evaluation occurs outside government. The trade magazine and the technical journal are screening mechanisms. And those individuals who attempt to keep abreast of the unpublished advances in their fields do their own evaluating. But to ask each potential user to evaluate all new technology in his mission area is to waste a valuable economic resource--skilled manpower.

Other means are necessary. Perhaps the originator of new knowledge could be encouraged to make a judgment of its utility. Perhaps professional societies and trade associations could assist in the performance of this function for the benefit of their memberships. Perhaps more specialized information centers could be created (hopefully, paid for--at least in large measure--by the users) to perform this task in given areas. Ideally, organizations whose members depend on knowledge of technological advances for their personal and professional well-being could perform the function for the benefit of their members.

The full burden of screening and evaluation should probably not be the responsibility of the taxpayer at large. The benefits of the function are, it would seem, spread too unevenly. Some form of cost sharing by the beneficiary is in order. This does not mean, of course, that he must pay for this service directly. He can pay for it in his purchase of resulting services--such as membership in specialized information centers or regional service centers; or by purchase of publications and announcement services that might result from evaluations; or by normal support of his professional society or trade association; or via some other secondary means.

Organizing for Retrieval

Few activities that appear so simple to the uninitiated are, in reality, as complex as the problem of arranging information in a manner that permits its easy retrieval for all those purposes for which it is relevant--and for those purposes only.

Use of report titles is soon recognized to be wholly inadequate as a basis for quick and accurate retrieval. Most titles are about as fully definitive of a report's content as any one of the proverbial descriptions the blind men gave after touching the elephant.

Consider three examples:

(1) Report title: "Materials Investigation: SNAP/50 Spur Program Mechanical Properties of TZM."

The descriptive terms used to categorize the document for later retrieval: Molybdenum alloys, Turbine parts, Ductility, Titanium alloys, Carbon alloys, Zirconium alloys, Processing, Forging, Tensile properties, Hardness, Recrystallization, Transition temperature, Creep, Microstructure, Stresses, Heat treatment, Turbine blades, Turbine wheels, Gas turbines.

While the descriptors add many dimensions to the ability to retrieve the report, they admittedly exhaust only a small portion of words and phrases that might be used in posing a question for which the information in the report would be relevant. For example, a system user involved in turbine design problems would readily retrieve the document from the system. But how about the designer of a propellor shaft--for whom it is possible that the information might be equally important? He would have to phrase his question in terms other than product language--in other words, design a more imaginative search strategy--in order to retrieve the document. But not too much imaginative would be required in this case, because the document is indexed under both "stresses," and "forgings," likely areas for the shaft designer to search. The case does, however, illustrate the problem.

(2) Report title: "A System Analysis of Civil Defense Organization at the Regional, State, and Local Levels. Initial Report: System Definition and Problem Identification."

The descriptors used were: Civil defense systems, management planning, U. S. government, Department of Defense, National defense, Management control systems, Management engineering, Warning systems, Survival, Food, Water supplies, Communication systems, Transportation, Medical personnel, Medical supplies, Civil defense personnel, Education, Economics, Banking, Urban areas.

This example illustrates the problem on the other end of the spectrum from the first example. In this case, it appears highly likely that the document could be retrieved in numerous cases where it was not relevant. The descriptors used are extremely broad. To keep from having this document turn up numerous times when it is not wanted, a different kind of intellectual activity is required in the design of the search strategy--extensive limitations must be imposed in forming the question to be asked of the computerized system in which this document is located.

It is also possible that the document will not be found by some potential users to whom the information contained in it might be important.[118] For example, a new and useful analytical technique might have been used in arriving at the system definition set forth in the report. But the descriptors used would not likely signal that fact.

(3) Title: "Phase Transformations In The Alloy Ti: 8% Al; 1% Mo; 1%V.[119]

Descriptive terms used: Titanium alloys, Phase Studies, Aluminum alloys, Molybdenum alloys, Vanadium alloys, Microstructure, Heat treatment, Transition temperature, Electron

118. The authors of this paper have not analyzed the document in question; its use here is purely to illustrate a point.

119. Refers to a titanium alloy containing 8 per cent aluminum, 1 per cent molybdenum, and 1 per cent vanadium.

diffraction analysis, Crystal lattices, Transformations, Martensite, Quenching (Cooling), Aging (Materials), Crystal lattice defects, Mechanical properties, Deformation.

This set of descriptors illustrates an additional point, i.e., the necessity to define (by additional terms in combination with the descriptor) more precisely in cases where a word had a multiplicity of meaning, such as quenching and aging.

It becomes quickly apparent, then, that indexing poses a major dilemma: Be conservative in the terms used and the document will not be found for many examples where it might be relevant; be liberal in describing the document and it will show up as an unwanted nuisance far too frequently.

Some solutions exist. One partial answer is the use of hierarchical description methods with considerable cross-referencing.

Another is the development of multiple systems, each to serve a body of users with reasonably homogenous interests and language, with separate sets of descriptors developed to serve each body of users. The cost of operation of such systems is obviously expensive. But the economic feasibility of moving in that direction should likely be more fully explored. There are significant trade-offs between the cost of performing that function and the time savings that would result from reducing the need to examine the abstracts of numerous unwanted documents--plus the advantage of retrieving a greater proportion of the relevant information in the system in answer to any given question.

The entire question might be better analyzed if more research in the documentation field were performed from a user-oriented (rather than source-oriented) viewpoint.

The question of abstracting comes up in the same context. With most mechanized systems--and many manual systems--the seeker of information is supplied a set of abstracts as a result of an information search. Seldom would it be practical, under any conditions, to deliver a full set of documents. (The sheer awesomeness that would result from the stacking of thirty pounds of paper on a man's desk in response to an inquiry would defeat the utility of the system, let alone other obvious problems of logistics and cost.) The seeker of information is then in a position of making his own evaluation--determining which documents he wants to examine in full--on the basis of the content of the abstract. The degree to which the abstract mirrors the content of the document then becomes crucial. Perhaps no one is better equipped to write an abstract than is the author of the document; his doing so, it seems, should be (and is being)encouraged. But this also raises a spectre--unless there is an element of policing involved. The generator of information, bound by a contractual responsibility to report new technology resulting from his government-sponsored effort, can conceivably do so but--in the quest of proprietary gain--shield that information from others who might exploit it by writing an abstract that does not indicate the findings he seeks to withhold. Of course, that would be dishonest and therefore, hopefully, such occurrences would be rare. It has been suggested that such attempts at shielding of information would be automatically discovered by the competition's monitoring of the output of any contractor. But that is far from a foolproof device--even assuming every contractor's immediate competition did read his reports. In the course of research, a sensing device might be modified in a way to make it commercially attractive to a broad market. The competition, none of them in the business of making laboratory instruments, might by-pass that information on the basis of its being "incidental" to the subject of the report and outside their area of interest.

But the likelihood of that becoming a major problem can be easily exaggerated. Taking that chance would probably be worth the value of having author-written abstracts.

The entire subject of organizing information for better retrieval is one that demands continuing attention by imaginative researchers. Such work should be encouraged by the government and private groups alike.

Contributions to this area are being made from numerous quarters, public and private, including OSIS, AEC, NASA, NIH, and many others. But the problem deserves increased emphasis.

Some attention might also be given to the question of categorization of information in announcement journals. For documents are seldom listed in announcement journals under all of the descriptors used to categorize them in the computer. Doing so in a single journal, for any one of the major agencies supporting R&D, would be impractical.

The question might be partially resolved, however, by the publication of a range of announcement journals, each aimed at a more specific audience. This might be a worthy project for some specialized professional societies.

An aid in resolving the problem is regular publication of bibliographies in both broad and narrow topical areas. Continuing bibliographies, regularly updated, now being produced by some groups, are a considerable aid.

Attention to Significance

Earlier in this paper, the importance of incremental advances in technology was emphasized. The new lubricant formulation, the new circuit design, the new inspection technique, and the improved composite material--while having widespread potential utility--are rarely of sufficient significance to start a buzzing in the technical grapevines that rapidly carry the news of those rare advances of exceptional immediate significance.

But incremental advances of that nature are often deserving of special communication. Consideration might be given to means of bringing them to the attention of potential users, on a selective basis, more rapidly.

"Fast Announcements" and "Tech Briefs" are two existing means of doing so. Others might be considered.

Solicitation of the cooperation of specialized business publications in the performance of that function should be encouraged. A more rapid means of communicating such information to the correct audiences would be difficult to devise at low cost.

Knitting the Elements

Frequently, several seemingly unrelated advances occuring at about the same time derive special significance when examined in composite. And the addition of a new item of information to a bank of other pieces of information can give the entire resource new significance.

The related advances can occur in fields traditionally far removed from one another--such as a medical discipline and a subdiscipline of electronic engineering.

This calls for switching mechanisms among information systems. Specialized information centers, in a few cases, perform such functions today.

New methods must be found, including mechanical or electronic aids that will speed the process.

Federal Government encouragement of research and exploration in this area is recommended.

Encouraging Use

Many who could benefit from technology transferring efforts have yet to be exposed to the advantages. And many others, discouraged by attempts at earlier times when little could be done to assist them, must again be exposed.

Information is a marketable commodity--if it means certain tests, such as significance, currency, relevancy, ease of availability, and comprehensiveness. But few practitioners in information services or technology transfer programs employ a total marketing approach.

Bill Knox has urged:[120] "Let us look at information services as a business--a business with service as its product--not abstracts, not indexes, not books, but service... Let us concentrate on the marketing side--too long ignored--not on the production side. The major attention and financial support given to hardware and information-processing techniques indicates an over-emphasis on production variables."

He adds: "Marketing information services in the way it should be done will probably not be easy. It will require new attitudes, new patterns of thought, new approaches--and new people. The record speaks for itself."

What will be required on technology channeling mechanisms that can generate payment for value received? Several points are obvious:

(1) Information service and technology transfer people must recognize the existence of segmented markets. Tailored services must be proffered to definable groups and subgroups. Selective dissemination services will not be sufficient (though they represent a significant step forward). Needed will be better switching mechanisms, some thoughtful repackaging of information, better categorization at the input side and better "interest profile" building on the output side, better analysis of document content, more emphasis on interpretation of the <u>why</u> and <u>what it means</u> instead of the mere presentation of <u>what</u> and <u>when</u>.

(2) Improved local access will likely enhance the marketability of information on new technology.

120. Knox, William T., "Marketing-Oriented Information Services," Speech at Joint Dinner Meeting of the American Documentation Institute, Americal Medical Writers Association, Society of Technical Writers and Publishers, and Special Libraries Association, Washington, D. C., March 15, 1965.

(3) Better referral services will be required; successful service organizations seldom tell their customers "no."

(4) More communicators, sociologists, and economists might be needed to add to the engineers, scientists, and documentalists that make up the full complement of knowhow in many centers today.

(5) More effort will be expended to determine the real problems and objectives of a potential user of technical information--not just blind faith in what he feels to be his problems. And some imaginative effort to interest the potential user in new technology outside his stated sphere of interest--but within his reasonable sphere when viewed objectively--might pay handsome dividends.

(6) Certainly, we need to learn much more about how new ideas become accepted (or rejected) within organizations.

Doing these things will take the missionaries for new technology several giant steps toward the goal Bill Knox has described as "remembering that the real needs of the consumer encompass not only the product itself, but also the values associated with its delivery and the process of consuming it."[121]

Joining Present and Future

The existence of some fragments of technology can and does encourage investment in the development of needed additions. But sometimes, after considerable development cost, it is discovered that someone else got there first. This should or could be avoided in the broad area of the public domain, if possible.

Technology transfer implies not only the provision of what now exists but the indication of what factors are sure to bear upon it.

121. Ibid.

The availability of information on a wide range of ongoing efforts, funded by federal agencies, would be useful. It would be especially valuable in combination with information of the results of completed R&D. The combination permits the offering of a new dimension of interpretation and referral.

The initial moves toward cooperation of SIE and the Clearinghouse have been made. This may be helpful. But far more can be done along these lines.

Permission to "Browse"

Technology transfer is often looked upon as a problem-solving mechanism only. Certainly, it is that--but it is also much more. It can be a means of bringing about ideas for the solution of problems not yet recognized and the meeting of objectives not yet defined.

Bringing that about requires the development of methods that allow people to browse through the technology available--much as a do-it-yourselfer shops about in a hardware store or a reader scans the contents of a magazine.

Since the volume of information available demands the use of mechanized systems today, allowance for browsing must be brought about mechanically and electronically. A step in that direction will be the use of remote consoles tied to a central information bank on a computer time sharing basis. Project MAC at MIT is the current pacesetter for systems of this type. NASA's Scientific and Technical Information Division is examining the feasability of such a system on an experimental basis.

Meeting this requirement--as well as others--demands compatibility among information systems. COSATI should be encouraged to continue to strive for coordination of systems among federal agencies. And efforts to make government and private systems compatible must be promulgated.

Planning Synergism

Two plus two can be five--the whole can have greater value than the sum of the parts. That happens when two or more technological advances, each of relatively minor significance in themselves, dovetail to form a useful new set of principles or the basis for invention of a new device or process.

Synergism is hard to plan. But some approaches that might have that effect can be considered.

For example, consider convening a group of technical people each of whom serves a different market but all of whom share a common technical base. For example, assume the common technical base is manipulators and devices to extend human physical capability. Assume the market orientations represented are prosthetic devices, manipulator systems for underwater plumbing and related work, material handling equipment for hot or otherwise uncomfortable environments, and the human factors engineering aspect of the transportation industry. Assume these people were brought together in an environment conducive to innovation and idea exchange for several weeks or months; their efforts were coordinated, lubricated, catalyzed, and focused by a trained mediator with knowledge of the technology involved; and made available to them was the resource of the existing inventory of technical information relating to the field (in a useful form). Isn't it possible that they would spark one another to innovative efforts of higher quality and greater imagination than could have been achieved without the advantage of being exposed to numerous other viewpoints on similar problems?

Professional societies, trade associations, specialized information centers, and other groups--especially those that are interdisciplinary or are made up of people who have a commonality of interest but a multiplicity of outlooks--might serve as forums for technology utilization efforts aimed at this objective. (And much might be learned about the creative process in the bargain.)

The Quality of Receivership

In terms of understanding how to create a climate for innovation, society today is long on theories and short on substantive knowledge. We may also be long on apathy.

But--as has been repeatedly emphasized--new technology seldom occurs in "off-the-shelf packages." Innovations originating in the military/space/nuclear realm generally require adaptation for employment in other contexts. Sometimes, innovation of a higher order is required to make successful adaption than was needed to conceive the original advance. And the out-of-pocket costs can be high.

Obviously, there would be a high return on an investment that would in fact define the elements of a "creative climate," or that would determine the characteristics that set the innovative person apart from others, or that would bring about an understanding of the essential ingredients of entrepreneurship.

Encouragement of research in the fields of focusing on those questions is recommended. Devising means of overcoming the barriers to technology transfer--and, perhaps more importantly--determining how to provide incentives for the utilization of available technology are goals worth pursuing.

In the context of improving "the quality of receivership," the recommendations of the Weinberg Committee to the technical community deserve repeating:[122]

(1) The technical community must recognize that handling of technical information is a worthy and integral part of science. "Such scientists must create new science, not just shuffle documents: their activities of reviewing, writing books, criticizing, and synthesizing are as much a part of science as is traditional research."

122. Science, Government, and Information, op. cit.

(2) The individual author must accept more responsibility for subsequent retrieval of what is published. (By that, the committee means authors of technical papers should title their papers in an informative manner; index their contributions with key words taken from standard thesauri; write informative abstracts; and refrain from unnecessary publication.)

(3) Techniques of handling information must be widely taught.

(4) The technical community must explore and exploit new switching methods. "The information transfer network is held together by an array of switching devices that connect the user with the information (as contrasted with the documents) he needs. As the amount of information grows, more ingenuity will be needed to find effective switching mechanisms, if only because the capacity of the human mind places a limit on how much information can be assimilated. The technical community must courageously explore new modes for information processing and retrieval. Among the schemes that ought to be exploited more fully are:

"Specialized information centers--the panel sees the specialized information center as a major key to the rationalization of our information system. Ultimately, we believe the specialized center will become the accepted retailer of information, switching, interpreting, and otherwise processing information from the large wholesale depositories and archival journals to the individual user. The panel therefore urges that more and better specialized centers be established.

"B. Central depositories--a central depository to which authors submit manuscripts that are announced and then distributed upon request may ease the technical problems of switching documents quickly and discriminately between user (particularly a specialized center) and source.

"C. Mechanized information processing. The panel recognizes that mechanical equipment offers hope for easing the information problem.

"D. Development of software. Hardware alone is not a panacea for difficulties of information retrieval. Software, including methods of analyzing, indexing, and programming, is at least as necessary for successful information retrieval."

(5) Uniformity and compatibility are desirable. "Since the entire information system is a network of separate subsystems, rapid and efficient switching between the different elements of the system is essential."

Personal Involvement

The written word is essential to technology transfer. But it is insufficient for effective transfer. Required is considerable personal involvement and person to person communication.

"The implications of a new technology in a variety of fields cannot be transferred by the written word. Some interplay between individuals is necessary to permit modification of the ideas of both the giver and the receiver in order to have a meshing of the proposals of each. Therefore, to increase the rate of technology utilization, a means must be provided to permit a meeting of qualified individuals. Publication is an important step in this process, but it is only the first step. Its primary purpose is to bring to the attention of the proper individuals the fact that certain information is available and to identify its source, thereby opening the way to subsequent communication between people with mutual interests. It is necessary to set up a system by which this can be accomplished and a special effort should be made to clarify the procedure to be followed."[123]

The kinds of follow-up communication required to achieve the transfer of technology, indicating the need for considerable personal involvement in the process, have been pointed out by Arthur D. Little, Inc.:[124] "The most frequent requests for further information were of a detailed nature--they related to the conditions of NASA's offer, the results of patent searches, the status of NASA lab work, the results obtained in actual use or during crutial tests (of performance, reliability, rate of wear, etc.). We encountered requests for models, samples, and engineering drawings. In some cases we found that written material concerning the innovation we proposed to discuss was already in the company files, although no action had been taken on it. One company obtained a license on a slit-regulated gas bearing concept as a result of our presentation--but they already had a copy of the patent in their engineering files."

123. Transference of Non-Nuclear Technology, etc., op. cit.

124. Technology Transfer and the Technology Utilization Program, op. cit.

Another experienced practicioner of technology transfer, Philip Wright, has reported:[125] "It is demonstrably evident that a critical point in the transfer and utilization mechanism is the personal confrontation of the intended user with the innovator. Such a confrontation, if skillfully managed and responsibly contributed to by all parties, generally transfers to and generates within the user that degree of emotive enthusiasm so psychologically necessary for embarking on a new endeavor characterized by educated guesses about immeasurable unknowns.

"It does seem that transfer and utilization is, in general, optimized if the effort is oriented in the first place towards one innovation and is combined with a positive advocacy on its behalf which is not abandoned until and unless valid technical or commercial reasons are discovered which makes it pointless to continue."

Mr. Wright's latter point--the requirement for an advocate--will be touched upon next.

The 'Personal Champion'

A wealth of experience on a variety of fronts documents the assertion that championing of the technology--by the inventor, the man who visualizes the application, an intermediary, the management of the firm in which the concept might be used, or by a person or group charged with a responsibility for the identification and use of new technology--will greatly enhance the odds of it being employed.

A company employs purchasing agents to seek out, evaluate, and bring into the firm the optimum materials and supplies. Why not then new technology agents to seek out, evaluate, and bring into the firm the best and most useful new knowledge? These technology agents would be unusual people--to whom an air travel card and a telephone would be far more important than an office and desk. They are generalists--they have a technical bent but

125. Wright, Philip, Final Report on 1964 Activities Relating To A Study Contract To Develop Dissemination Procedures For Use With the Industrial Applications Program, (University of Maryland, June 1965).

are not necessarily engineers or scientists. They understand the arithmetic of business but are certainly not accountants or mathematicians. They are imaginative people. They can readily grasp new concepts. They are fully informed on their company's manufacturing capabilities and marketing objectives. They are outstanding communicators. They know how to sell ideas--and are capable of dealing effectively at all levels inside and outside the firm. They know how to get themselves attached to those industrial, governmental and professional grapevines on which the fruits of knowledge most important to their companies grow and flow. These technology agents are really technoeconomists and sociotechnologists.[126]

The technology agent, for maximum effectiveness, should have the back-up support of a group of professionals who might be called "utilization technologists." These are special kinds of in-house application engineers--or, more accurately, adaptioneers.

Their role is to put to use the relevant new knowledge gathered from sources outside the firm. A separate function is proposed to perform this task--but is not essential if the existing engineering groups do not suffer from NIH (Not Invented Here) and if they recognize that it is seldom possible to pick up a piece of hardware developed for one reason and put it to use in a totally different context. In other words, those performing this task must have extrapolative ability and the capability to see associations between the underlying concepts of an innovation and the basis of the need area in which it might be applied.

Effort should be expended, in both the private and public sectors, to find men with the required capabilities and interests to perform these functions.

Organizations seeking to benefit from the results of government R&D should also determine whether their organizational framework is designed to permit the ready inflow and acceptance of technology generated outside the firm.

126. Howick, George J., "Some Marketing and Managerial Implications of New Technology," Speech at American Metal Climax Corp. luncheon meeting, New York, September 20, 1965.

Specialized Information Centers

As especially promising mechanisms for technology transfer, specialized information centers deserve a mention in the current context.

The Department of Defense has placed renewed emphasis on this mechanism recently by naming some centers previously operated by the individual services as Department-wide centers.

For example, the Navy has been assigned responsibility for the operation of five centers to serve the entire Defense community. The centers are: (1) Centralizing Activity for Shock, Vibration, and Associated Environments, (2) Chemical Propulsion Information Agency, (3) Hibernation Information Exchange, (4) Infrared Information and Analysis Center, (5) National Oceanographic Data Center.

Most specialized information centers in existence today--including those within the Department of Defense--were established to service mission-oriented needs. For example, consider the Shock and Vibration Center. In 1947, the Navy discovered that replacement jet engines for its airplanes were delivered in damaged condition too frequently. It turned to the Naval Research Laboratories for help because these laboratories had a shock and vibration branch concerned with developing criteria for, and testing of, electronic equipment designed to remain operable on a ship subjected to gunfire. The solution to the jet engine problem was to invite manufacturers, cargo handlers, transport companies, and packers to meet and discuss what could be done about it. The response was excellent. The Army and the Air Force asked to join the Navy as the symposia grew in number and in attendance. And a specialized center came into being. In 1954, the Research and Development Board of DOD accepted responsibility for the operation and ran it as a tri-service effort (with some NASA support in later years) until 1964, when it became a DOD-sponsored activity under Navy management. Many rocket engine components are more delicate than jet engines so the interest in the subject has increased to the point where four days, instead of the usual three, were devoted to the Shock and Vibration Symposium this year, where 320 papers were submitted.

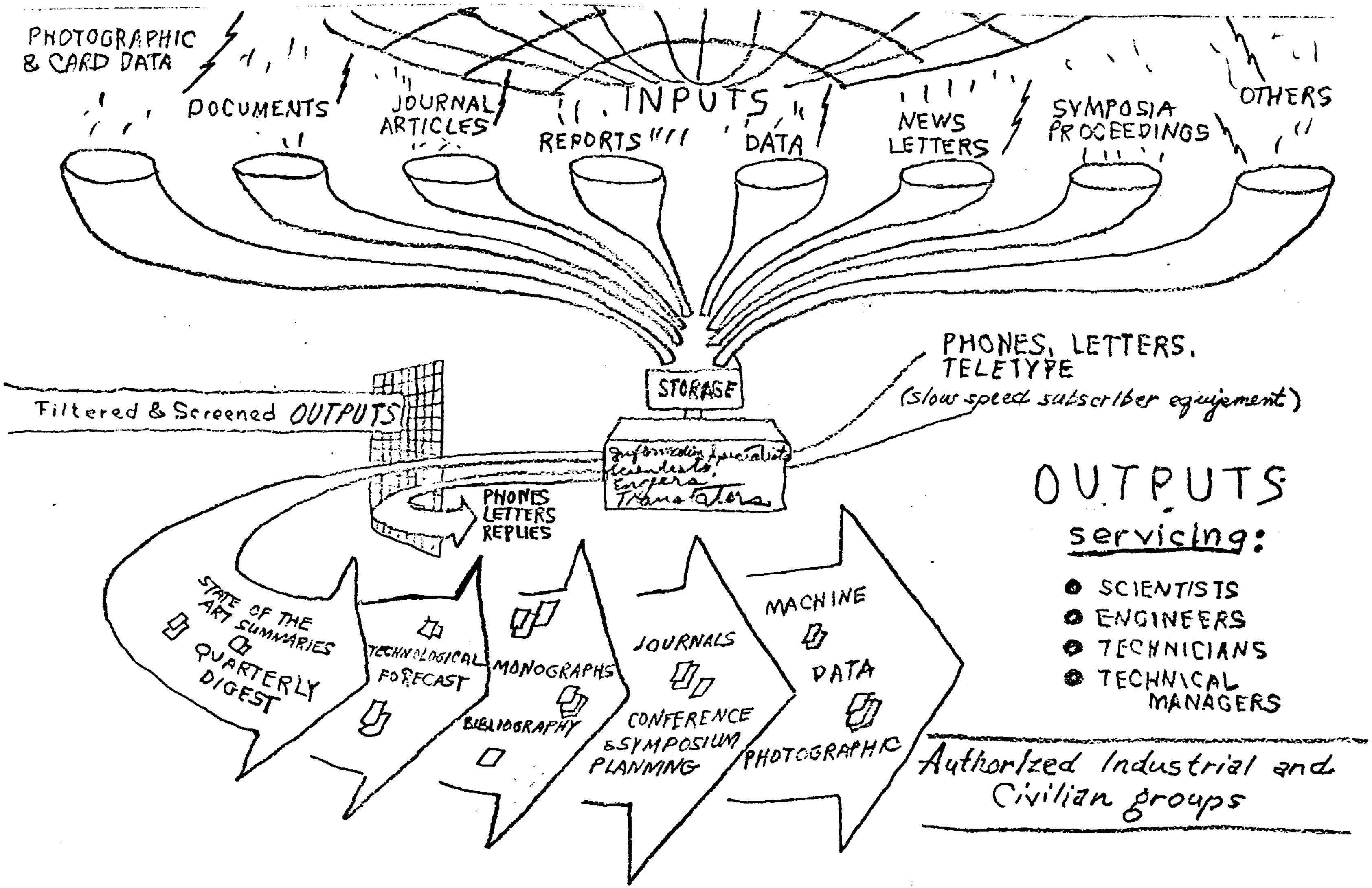
For effective operation, a specialized information center must be staffed by competent authorities in the field of coverage who are good transfer agents in addition to being good scientists and/or engineers.

A wide range of sources and a multiplicity of information transfer mechanisms, fitted to the requirements of particular users of the center, are employed by the better managed centers. The illustration on the following page, of the Army Research Office's concept of Information Analysis Centers, makes the point.

But the mere establishment of more such centers--there are now about 300 of them in the U.S.--will not aid the technology channeling effort unless these centers meet the criteria indicated by the Weinberg Panel. The panel called for centers to be staffed by a group, scientists and/or engineers engaged in substantive work in a delineated field of science or technology (together with one or more experts in information science), to organize, evaluate, summarize, criticize, and disseminate the "literature" or "information base" of that field. The output of a specialized technical information center includes bibliographic information plus abstracts and summaries plus reviews and criticisms plus "scientific intelligence" digests plus, perhaps, newsletters and loans or gifts of copies of documents. A specialized technical information center is best associated with an active laboratory or development agency, and most of the people who participate in the basic work of the center do so in connection with their substantive work in research or engineering.

A more recent panel, the Office of Science and Technology Panel on Scientific and Technical Communication, reinforced the judgment of the Weinberg Committee, but added a note of warning: "We share in the Weinberg Panel's high regard for the concept. We have heard about several centers that implement the concept well and that are very effective. On the basis of our limited study of the situation, however, we are afraid that there are too many specialized technical information centers that have little more than a nominal connection with the Weinberg Panel's concept. Some of these have come into being because it has

INFORMATION ANALYSIS CENTER



become "the thing to do" for a government agency that supports research in a given field to set up a center in that field. Indeed, if agency A does not hurry, agency B will set up the center for the field in question. There are now between 200 and 400 centers for specialized technical information. We are afraid that, in many of them, an excellent concept may be suffering from merely-nominal and low-quality implementation."

APPENDIX A

Statistics on Federal Expenditures for Research and Development

This Appendix reproduces statistics on government expenditures for research and development, as compiled by the National Science Foundation and published in Federal Funds for Research, Development and Other Scientific Activities, Fiscal Years 1964, 1965, and 1966, Volume XIV, NSF Publication Number: NSF 65-19, July 1965.

TABLE C-1. *Summary of Federal funds for research, development, and R&D plant, fiscal years 1964, 1965, and 1966*

[Millions of dollars]

Item	Actual 1964	Estimates 1965	Estimates 1966
TOTAL EXPENDITURES FOR RESEARCH, DEVELOPMENT, AND R&D PLANT	14,693.9	15,371.5	15,437.7
RESEARCH AND DEVELOPMENT	13,649.8	14,038.2	14,300.1
R&D PLANT	1,044.1	1,333.3	1,137.6
TOTAL OBLIGATIONS FOR RESEARCH, DEVELOPMENT, AND R&D PLANT	15,310.4	16,487.7	16,145.7
RESEARCH AND DEVELOPMENT	14,132.9	14,828.5	15,280.3
Total research	4,541.1	5,056.9	5,607.2
Basic research	1,573.9	1,807.9	2,049.5
Applied research	2,967.2	3,249.0	3,557.7
Development	9,591.7	9,771.6	9,673.1
R&D PLANT	1,177.5	1,659.2	865.4
RESEARCH AND DEVELOPMENT:			
Performers:			
Federal Government	2,827.7	3,141.3	3,177.7
Profit organizations, proper	8,567.2	8,793.4	8,976.7
Profit organization research centers	492.3	467.9	464.6
Educational institutions, proper	1,061.4	1,178.0	1,350.1
Educational institution research centers	543.5	559.4	587.9
Other nonprofit organizations, proper	303.8	321.6	346.2
Other nonprofit organization research centers	224.8	236.7	234.9
Other domestic	40.2	47.1	55.0
Foreign	72.1	83.2	87.3
Research:			
Performers:			
Federal Government	1,330.9	1,542.3	1,580.2
Profit organizations, proper	1,441.8	1,576.1	1,831.8
Profit organization research centers	66.7	64.3	70.0
Educational institutions, proper	997.6	1,109.8	1,282.1
Educational institution research centers	295.2	316.5	348.2
Other nonprofit organizations, proper	233.5	250.4	275.6
Other nonprofit organization research centers	81.2	93.4	99.6
Other domestic	34.8	41.5	48.5
Foreign	59.4	62.4	71.3
Field of science:			
Life sciences, total	1,065.4	1,212.7	1,343.3
Biological sciences	223.0	269.5	307.7
Medical sciences	762.7	843.5	931.4
Agricultural sciences	79.6	99.7	104.1
Psychological sciences	96.3	117.2	141.8
Physical sciences, total	3,196.3	3,472.2	3,816.8
Physical sciences, proper	1,597.4	1,708.9	1,877.7
Mathematical sciences	98.0	103.9	127.6
Engineering sciences	1,500.9	1,659.3	1,811.5
Social sciences	102.7	129.5	155.5
Other sciences	80.5	125.4	149.8
Basic research:			
Performers:			
Federal Government	368.2	430.6	465.8
Profit organizations, proper	310.9	361.4	390.5
Profit organization research centers	27.6	28.3	31.4
Educational institutions, proper	551.9	633.1	756.6
Educational institution research centers	146.7	167.7	195.7
Other nonprofit organizations, proper	83.1	89.2	102.6
Other nonprofit organization research centers	47.4	53.5	60.8
Other domestic	12.7	15.1	17.3
Foreign	25.3	28.9	28.8

TABLE C-1. *Summary of Federal funds for research, development, and R&D plant, fiscal years 1964, 1965, and 1966*—Continued

[Millions of dollars]

Item	Actual 1964	Estimates	
		1965	1966
Research—Continued			
Field of science:			
Life sciences, total	441.0	517.9	586.4
Biological sciences	143.0	182.3	220.1
Medical sciences	273.6	302.4	331.1
Agricultural sciences	24.5	33.2	35.3
Psychological sciences	47.2	58.4	69.7
Physical sciences, total	1,049.9	1,184.1	1,331.0
Physical sciences, proper	862.1	975.5	1,105.1
Mathematical sciences	52.9	58.2	65.4
Engineering sciences	134.9	150.3	160.5
Social sciences	34.2	40.1	52.7
Other sciences	1.5	7.4	9.7
Applied Research:			
Performers:			
Federal Government	962.7	1,111.7	1,114.4
Profit organizations, proper	1,130.9	1,214.8	1,441.3
Profit organization research centers	39.1	36.0	38.6
Educational institutions, proper	445.7	476.7	525.5
Educational institution research centers	148.4	148.9	152.5
Other nonprofit organizations, proper	150.4	161.2	173.0
Other nonprofit organization research centers	33.8	39.9	38.7
Other domestic	22.1	26.4	31.2
Foreign	34.1	33.5	42.5
Field of Science:			
Life sciences, total	624.3	694.8	756.9
Biological sciences	80.0	87.2	87.7
Medical sciences	489.1	541.1	600.4
Agricultural sciences	55.2	66.5	68.9
Psychological sciences	49.0	58.8	72.1
Physical sciences, total	2,146.4	2,288.1	2,485.8
Physical sciences, proper	735.4	733.4	772.6
Mathematical sciences	45.1	45.7	62.2
Engineering sciences	1,365.9	1,509.0	1,651.0
Social sciences	68.5	89.3	102.8
Other sciences	79.0	118.0	140.1
Development:			
Performers:			
Federal Government	1,496.8	1,598.9	1,597.6
Profit organizations, proper	7,125.3	7,217.2	7,144.9
Profit organization research centers	425.7	403.7	394.6
Educational institutions, proper	63.8	68.1	68.0
Educational institutions research centers	248.4	242.8	239.6
Other nonprofit organizations, proper	70.2	71.2	70.6
Other nonprofit organization research centers	143.6	143.2	135.3
Other domestic	5.4	5.6	6.5
Foreign	12.6	20.8	16.0
R&D PLANT			
Federal civilian or military installations	974.5	1,330.2	589.1
Educational institutions	133.5	216.9	167.1
Other non-Federal sites	37.1	35.7	30.5
Foreign	32.4	76.4	78.7

TABLE C-2. FEDERAL FUNDS FOR RESEARCH, DEVELOPMENT, AND R&D PLANT, BY AGENCY, FISCAL YEARS 1964, 1965, AND 1966

-MILLIONS OF DOLLARS-

AGENCY AND SUBDIVISION	OBLIGATIONS			EXPENDITURES		
	ACTUAL	ESTIMATES		ACTUAL	ESTIMATES	
	1964	1965	1966	1964	1965	1966
TOTAL, ALL AGENCIES	15,310.4	16,487.7	16,145.7	14,693.9	15,371.5	15,437.7
DEPARTMENTS						
DEPARTMENT OF AGRICULTURE, TOTAL	191.4	257.0	249.3	183.4	231.3	257.7
AGRICULTURAL RESEARCH SERVICE	113.2	161.0	152.3	100.5	136.8	158.6
COOPERATIVE STATE RESEARCH SERVICE	42.8	50.3	52.7	41.5	49.9	52.4
ECONOMIC RESEARCH SERVICE	9.0	10.8	11.2	9.8	10.5	11.2
FARMER COOPERATIVE SERVICE	.7	.8	.8	.7	.7	.7
FOREST SERVICE	25.1	33.4	31.6	30.3	32.7	34.1
NATIONAL AGRICULTURAL LIBRARY	*	.1	.1	*	.1	.2
STATISTICAL REPORTING SERVICE	.5	.6	.6	.5	.6	.6
DEPARTMENT OF COMMERCE, TOTAL	98.6	90.5	87.6	84.5	98.0	93.0
AREA REDEVELOPMENT ADMINISTRATION	1.1	1.3	1.4	.7	1.0	1.2
BUREAU OF THE CENSUS	1.8	3.2	1.9	1.8	3.2	1.9
BUREAU OF PUBLIC ROADS	4.5	5.6	8.4	4.2	5.0	7.2
COAST AND GEODETIC SURVEY	4.1	3.7	10.7	9.6	10.1	7.3
MARITIME ADMINISTRATION	5.5	10.9	11.2	7.8	10.5	5.5
NATIONAL BUREAU OF STANDARDS	68.3	47.4	33.0	46.7	51.7	50.1
OFFICE OF BUSINESS ECONOMICS	2.1	2.4	2.8	2.0	2.3	2.7
PATENT OFFICE	.6	.7	.7	.6	.7	.7
TRANSPORTATION RESEARCH	1.2	3.0	3.2	.9	2.0	2.5
WEATHER BUREAU	9.5	12.4	14.4	10.3	11.6	13.9
DEPARTMENT OF DEFENSE, TOTAL	7,352.5	7,077.2	7,200.9	7,517.0	7,222.3	6,880.7
DEPARTMENT OF THE ARMY, TOTAL	1,389.3	1,503.0	1,521.4	1,413.6	1,482.3	1,452.1
RDT&E APPROPRIATIONS	1,321.0	1,400.0	1,430.0	1,338.0	1,400.0	1,375.0
CIVIL FUNCTIONS	4.0	4.6	5.4	4.0	4.6	5.4
DT&E SUPPORT FROM PROCUREMENT APPROPRIATIONS	6.1	12.9	6.0	7.0	13.9	6.0
PAY AND ALLOWANCES OF MILITARY PERSONNEL IN R&D	45.8	53.0	49.1	45.8	53.0	49.1
MILITARY CONSTRUCTION	12.3	32.4	31.0	18.8	10.8	16.7
DEPARTMENT OF THE NAVY, TOTAL	1,640.0	1,515.2	1,599.1	1,724.2	1,590.0	1,540.0
RDT&E APPROPRIATIONS	1,492.2	1,380.0	1,460.0	1,577.8	1,450.0	1,395.0
DT&E SUPPORT FROM PROCUREMENT APPROPRIATIONS	42.8	28.7	41.0	49.0	30.9	41.0
DT&E SUPPORT FROM OPERATIONS AND MAINTENANCE APPROPRIATIONS	26.0	26.9	21.2	28.1	26.1	22.9
PAY AND ALLOWANCES OF MILITARY PERSONNEL IN R&D	60.2	59.2	58.0	60.2	59.2	58.0
MILITARY CONSTRUCTION	18.8	20.4	19.0	9.1	23.7	23.2
DEPARTMENT OF THE AIR FORCE, TOTAL	3,822.6	3,433.1	3,422.3	3,951.1	3,616.6	3,384.4
RDT&E APPROPRIATIONS	3,591.9	3,210.0	3,170.0	3,721.6	3,350.0	3,140.0
DT&E SUPPORT FROM PROCUREMENT APPROPRIATIONS	21.1	23.3	23.1	24.1	25.1	23.1
DT&E SUPPORT FROM OPERATIONS AND MAINTENANCE APPROPRIATIONS	14.1	14.2	14.0	15.2	13.8	12.7
PAY AND ALLOWANCES OF MILITARY PERSONNEL IN R&D	157.0	165.3	158.0	157.0	165.3	158.0
MILITARY CONSTRUCTION	38.6	20.3	57.2	33.2	62.4	50.6
DEFENSE AGENCIES, TOTAL	488.8	495.2	493.1	406.9	487.7	464.5
RDT&E APPROPRIATIONS	467.9	491.7	490.0	384.0	475.0	460.0
MILITARY CONSTRUCTION	20.9	3.5	3.1	23.0	12.7	4.5
DEPARTMENTWIDE FUNDS	11.8	130.7	165.0	21.1	45.7	39.7
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	847.7	1,026.5	1,080.1	793.4	812.9	963.9
FOOD AND DRUG ADMINISTRATION	6.6	11.6	12.0	7.3	7.4	13.6
OFFICE OF EDUCATION	18.3	55.0	78.2	12.7	18.9	33.5
PUBLIC HEALTH SERVICE	792.2	924.4	948.8	751.0	753.5	879.5
NATIONAL INSTITUTES OF HEALTH	/707.8/	/827.9/	/837.4/	/679.1/	/661.8/	/760.2/
SAINT ELIZABETHS HOSPITAL	.3	.4	.4	.3	.4	.4
SOCIAL SECURITY ADMINISTRATION	2.2	2.2	2.8	1.8	2.4	2.8
VOCATIONAL REHABILITATION ADMINISTRATION	20.4	23.3	25.3	15.8	20.9	22.6
WELFARE ADMINISTRATION	7.9	9.7	12.7	4.5	9.3	11.6

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TABLE C-2. CONTINUED

AGENCY AND SUBDIVISION	OBLIGATIONS			EXPENDITURES		
	ACTUAL	ESTIMATES		ACTUAL	ESTIMATES	
	1964	1965	1966	1964	1965	1966
DEPARTMENT OF THE INTERIOR, TOTAL	114.3	144.0	151.8	102.0	126.7	138.7
BONNEVILLE POWER ADMINISTRATION	.9	3.2	.7	1.1	1.1	2.8
BUREAU OF COMMERCIAL FISHERIES	21.7	29.3	23.9	23.6	26.2	25.5
BUREAU OF LAND MANAGEMENT	.4	.6	.7	.4	.6	.7
BUREAU OF MINES	26.2	27.7	28.5	25.8	27.7	28.3
BUREAU OF OUTDOOR RECREATION	.1	.1	.1	.1	.1	.1
BUREAU OF RECLAMATION	1.8	3.5	3.4	1.8	3.5	3.4
BUREAU OF SPORT FISHERIES AND WILDLIFE	17.3	21.0	20.7	13.5	20.0	19.7
GEOLOGICAL SURVEY	24.5	28.0	29.4	22.0	22.4	22.9
NATIONAL PARK SERVICE	1.5	2.0	2.0	1.5	2.0	2.0
OFFICE OF COAL RESEARCH	6.8	6.4	7.4	2.6	6.4	7.4
OFFICE OF SALINE WATER	13.0	18.0	29.1	9.5	12.5	20.0
OFFICE OF WATER RESOURCES RESEARCH	.....	4.3	5.8	.....	4.3	5.8
DEPARTMENT OF LABOR, TOTAL	8.8	9.9	11.0	7.2	9.4	10.5
BUREAU OF APPRENTICESHIP AND TRAINING	.1	.1	.1	.1	.1	.1
BUREAU OF EMPLOYMENT SECURITY	1.0	1.4	2.0	1.0	1.4	2.0
BUREAU OF LABOR STANDARDS	.3	.3	.3	.3	.3	.3
BUREAU OF LABOR STATISTICS	2.4	2.5	3.3	2.3	2.4	3.2
OFFICE OF LABOR MANAGEMENT POLICY DEVELOPMENT	.1	.1	.1	.1	.1	.1
OFFICE OF MANPOWER, AUTOMATION, AND TRAINING	3.7	3.7	3.7	2.1	3.3	3.3
WAGE AND HOUR AND PUBLIC CONTRACTS DIVISIONS	1.1	1.5	1.3	1.1	1.5	1.3
WOMENS BUREAU	.2	.2	.2	.2	.2	.2
POST OFFICE DEPARTMENT	8.7	14.2	9.1	7.1	9.3	10.0
DEPARTMENT OF STATE, TOTAL	9.3	13.6	14.5	3.5	8.4	13.8
DEPARTMENTAL FUNDS	.1	.1	.3	.1	.1	.3
AGENCY FOR INTERNATIONAL DEVELOPMENT	9.1	13.4	14.3	3.4	8.2	13.5
DEPARTMENT OF THE TREASURY, TOTAL	3.0	4.2	4.4	3.0	4.2	4.4
BUREAU OF ENGRAVING AND PRINTING	.4	.5	.5	.4	.5	.5
UNITED STATES COAST GUARD	2.6	3.7	3.9	2.6	3.7	3.9
OTHER AGENCIES						
ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS	.2	.1	.1	.2	.1	.1
ATOMIC ENERGY COMMISSION	1,478.6	1,692.0	1,520.5	1,505.0	1,571.6	1,559.7
CIVIL AERONAUTICS BOARD	.1	.1	.1	.1	.1	.1
CIVIL SERVICE COMMISSION	.1	.2	.2	.1	.2	.2
FEDERAL AVIATION AGENCY	73.7	90.6	72.2	74.0	108.6	73.4
FEDERAL COMMUNICATIONS COMMISSION	.3	.3	.3	.3	.3	.3
FEDERAL HOME LOAN BANK BOARD	.1	.2	.2	.1	.2	.2
FEDERAL TRADE COMMISSION	.2	.3	.3	.2	.3	.3
HOUSING AND HOME FINANCE AGENCY	.2	.2	.3	.1	.2	.2
LIBRARY OF CONGRESS	.1	.1	.5	.1	.1	.5
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	4,842.2	5,733.2	5,319.8	4,171.0	4,900.0	5,100.0
NATIONAL SCIENCE FOUNDATION	224.4	266.6	345.2	189.8	201.4	258.7
OFFICE OF EMERGENCY PLANNING	.2	.5	1.4	.3	.2	.7
PEACE CORPS	.6	.6	1.4	.3	.5	.8
SMALL BUSINESS ADMINISTRATION	.3	.2	.5	.4	.6	.3
SMITHSONIAN INSTITUTION	9.0	7.7	10.8	6.0	8.9	9.5
TENNESSEE VALLEY AUTHORITY	5.2	5.9	6.2	5.2	5.9	6.2
UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY	5.7	7.2	10.2	5.0	8.1	7.9
UNITED STATES INFORMATION AGENCY	.6	.4	.2	.6	.7	.2
VETERANS ADMINISTRATION	34.3	44.3	46.5	34.1	41.3	45.9

TABLE C-3. FEDERAL FUNDS FOR TOTAL RESEARCH AND DEVELOPMENT, BY AGENCY, FISCAL YEARS 1964, 1965, AND 1966

-MILLIONS OF DOLLARS-

AGENCY AND SUBDIVISION	OBLIGATIONS			EXPENDITURES		
	ACTUAL	ESTIMATES		ACTUAL	ESTIMATES	
	1964	1965	1966	1964	1965	1966
TOTAL, ALL AGENCIES	14,132.9	14,828.5	15,280.3	13,649.8	14,038.2	14,300.1
DEPARTMENTS						
DEPARTMENT OF AGRICULTURE, TOTAL	189.0	227.4	232.8	178.4	215.4	235.1
AGRICULTURAL RESEARCH SERVICE	111.5	138.7	139.1	98.4	127.9	140.1
COOPERATIVE STATE RESEARCH SERVICE	42.8	47.1	50.7	41.5	46.7	50.4
ECONOMIC RESEARCH SERVICE	9.0	10.8	11.2	9.8	10.5	11.2
FARMER COOPERATIVE SERVICE	.7	.8	.8	.7	.7	.7
FOREST SERVICE	24.4	29.4	30.2	27.4	28.9	32.0
NATIONAL AGRICULTURAL LIBRARY	*	.1	.1	*	.1	.2
STATISTICAL REPORTING SERVICE	.5	.6	.6	.5	.6	.6
DEPARTMENT OF COMMERCE, TOTAL	53.8	69.3	75.6	53.4	65.2	67.2
AREA REDEVELOPMENT ADMINISTRATION	1.1	1.3	1.4	.7	1.0	1.2
BUREAU OF THE CENSUS	1.8	3.2	1.9	1.8	3.2	1.9
BUREAU OF PUBLIC ROADS	4.5	5.6	8.4	4.2	5.0	7.2
COAST AND GEODETIC SURVEY	2.3	2.2	2.3	2.2	2.0	2.1
MARITIME ADMINISTRATION	5.2	10.6	10.5	7.5	10.2	4.8
NATIONAL BUREAU OF STANDARDS	25.6	28.0	30.0	23.3	27.2	30.3
OFFICE OF BUSINESS ECONOMICS	2.1	2.4	2.8	2.0	2.3	2.7
PATENT OFFICE	.6	.7	.7	.6	.7	.7
TRANSPORTATION RESEARCH	1.2	3.0	3.2	.9	2.0	2.5
WEATHER BUREAU	9.5	12.4	14.4	10.2	11.6	13.9
DEPARTMENT OF DEFENSE, TOTAL	7,261.9	7,000.6	7,090.7	7,432.9	7,112.7	6,785.7
DEPARTMENT OF THE ARMY, TOTAL	1,376.9	1,470.6	1,490.4	1,394.8	1,471.5	1,435.4
RDT&E APPROPRIATIONS	1,321.0	1,400.0	1,430.0	1,338.0	1,400.0	1,375.0
CIVIL FUNCTIONS	4.0	4.6	5.4	4.0	4.6	5.4
DT&E SUPPORT FROM PROCUREMENT APPROPRIATIONS	6.1	12.9	6.0	7.0	13.9	6.0
PAY AND ALLOWANCES OF MILITARY PERSONNEL IN R&D	45.8	53.0	49.1	45.8	53.0	49.1
DEPARTMENT OF THE NAVY, TOTAL	1,621.2	1,494.9	1,580.1	1,715.1	1,566.3	1,516.8
RDT&E APPROPRIATIONS	1,492.2	1,380.0	1,460.0	1,577.8	1,450.0	1,395.0
DT&E SUPPORT FROM PROCUREMENT APPROPRIATIONS	42.8	28.7	41.0	49.0	30.9	41.0
DT&E SUPPORT FROM OPERATIONS AND MAINTENANCE APPROPRIATIONS	26.0	26.9	21.2	28.1	26.1	22.9
PAY AND ALLOWANCES OF MILITARY PERSONNEL IN R&D	60.2	59.2	58.0	60.2	59.2	58.0
DEPARTMENT OF THE AIR FORCE, TOTAL	3,784.0	3,412.8	3,365.1	3,917.9	3,554.2	3,333.8
RDT&E APPROPRIATIONS	3,591.9	3,210.0	3,170.0	3,721.6	3,350.0	3,140.0
DT&E SUPPORT FROM PROCUREMENT APPROPRIATIONS	21.1	23.3	23.1	24.1	25.1	23.1
DT&E SUPPORT FROM OPERATIONS AND MAINTENANCE APPROPRIATIONS	14.1	14.2	14.0	15.2	13.8	12.7
PAY AND ALLOWANCES OF MILITARY PERSONNEL IN R&D	157.0	165.3	158.0	157.0	165.3	158.0
DEFENSE AGENCIES, TOTAL	467.9	491.7	490.0	384.0	475.0	460.0
RDT&E APPROPRIATIONS	467.9	491.7	490.0	384.0	475.0	460.0
DEPARTMENTWIDE FUNDS	11.8	130.7	165.0	21.1	45.7	39.7
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	776.9	879.3	979.1	746.9	735.0	860.3
FOOD AND DRUG ADMINISTRATION	6.0	7.2	10.0	6.3	6.9	9.6
OFFICE OF EDUCATION	18.3	37.0	52.2	12.7	18.9	27.5
PUBLIC HEALTH SERVICE	722.0	799.6	875.7	705.5	676.2	785.8
NATIONAL INSTITUTES OF HEALTH	/651.0/	/720.0/	/775.2/	/638.0/	/600.8/	/692.6/
SAINT ELIZABETHS HOSPITAL	.3	.4	.4	.3	.4	.4
SOCIAL SECURITY ADMINISTRATION	2.2	2.2	2.8	1.8	2.4	2.6
VOCATIONAL REHABILITATION ADMINISTRATION	20.4	23.3	25.3	15.8	20.9	22.6
WELFARE ADMINISTRATION	7.9	9.7	12.7	4.5	9.3	11.6

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TABLE C-3. CONTINUED

AGENCY AND SUBDIVISION	OBLIGATIONS			EXPENDITURES		
	ACTUAL	ESTIMATES		ACTUAL	ESTIMATES	
	1964	1965	1966	1964	1965	1966
DEPARTMENT OF THE INTERIOR, TOTAL	106.4	123.4	137.0	92.3	113.3	120.5
BONNEVILLE POWER ADMINISTRATION	.3	.3	.4	.3	.3	.3
BUREAU OF COMMERCIAL FISHERIES	18.2	20.7	23.0	18.5	20.5	22.2
BUREAU OF LAND MANAGEMENT	.4	.6	.7	.4	.6	.7
BUREAU OF MINES	25.6	27.7	28.5	25.5	27.3	28.3
BUREAU OF OUTDOOR RECREATION	.1	.1	.1	.1	.1	.1
BUREAU OF RECLAMATION	1.8	3.4	3.3	1.8	3.4	3.3
BUREAU OF SPORT FISHERIES AND WILDLIFE	16.3	18.9	19.9	11.6	17.8	18.8
GEOLOGICAL SURVEY	24.3	27.0	29.1	21.9	21.8	22.4
NATIONAL PARK SERVICE	1.5	2.0	2.0	1.5	2.0	2.0
OFFICE OF COAL RESEARCH	5.3	3.9	3.4	2.4	3.9	3.4
OFFICE OF SALINE WATER	12.6	14.6	20.8	8.3	11.3	13.2
OFFICE OF WATER RESOURCES RESEARCH	.....	4.3	5.8	.....	4.3	5.8
DEPARTMENT OF LABOR, TOTAL	8.8	9.9	11.0	7.2	9.4	10.5
BUREAU OF APPRENTICESHIP AND TRAINING	.1	.1	.1	.1	.1	.1
BUREAU OF EMPLOYMENT SECURITY	1.0	1.4	2.0	1.0	1.4	2.0
BUREAU OF LABOR STANDARDS	.3	.3	.3	.3	.3	.3
BUREAU OF LABOR STATISTICS	2.4	2.5	3.3	2.3	2.4	3.2
OFFICE OF LABOR MANAGEMENT POLICY DEVELOPMENT	.1	.1	.1	.1	.1	.1
OFFICE OF MANPOWER, AUTOMATION, AND TRAINING	3.7	3.7	3.7	2.1	3.3	3.3
WAGE AND HOUR AND PUBLIC CONTRACTS DIVISIONS	1.1	1.5	1.3	1.1	1.5	1.3
WOMENS BUREAU	.2	.2	.2	.2	.2	.2
POST OFFICE DEPARTMENT	8.7	14.2	9.0	7.1	9.3	9.9
DEPARTMENT OF STATE, TOTAL	9.3	13.6	14.5	3.2	7.7	12.5
DEPARTMENTAL FUNDS	.1	.1	.3	.1	.1	.3
AGENCY FOR INTERNATIONAL DEVELOPMENT	9.1	13.4	14.3	3.0	7.5	12.3
DEPARTMENT OF THE TREASURY, TOTAL	2.2	3.1	3.7	2.2	3.1	3.7
BUREAU OF ENGRAVING AND PRINTING	.4	.5	.5	.4	.5	.5
UNITED STATES COAST GUARD	1.8	2.5	3.1	1.8	2.5	3.1
OTHER AGENCIES						
ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS	.2	.1	.1	.2	.1	.1
ATOMIC ENERGY COMMISSION	1,236.0	1,270.6	1,292.0	1,236.0	1,270.6	1,292.0
CIVIL AERONAUTICS BOARD	.1	.1	.1	.1	.1	.1
CIVIL SERVICE COMMISSION	.1	.2	.2	.1	.2	.2
FEDERAL AVIATION AGENCY	62.8	76.3	69.2	62.7	97.9	71.1
FEDERAL COMMUNICATIONS COMMISSION	.3	.3	.3	.3	.3	.3
FEDERAL HOME LOAN BANK BOARD	.1	.2	.2	.1	.2	.2
FEDERAL TRADE COMMISSION	.2	.3	.3	.2	.3	.3
HOUSING AND HOME FINANCE AGENCY	.2	.2	.3	.1	.2	.2
LIBRARY OF CONGRESS	.1	.1	.5	.1	.1	.5
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	4,199.6	4,881.6	5,021.3	3,637.2	4,184.0	4,567.1
NATIONAL SCIENCE FOUNDATION	164.6	198.7	271.4	140.7	152.2	197.8
OFFICE OF EMERGENCY PLANNING	.2	.5	1.4	.3	.2	.7
PEACE CORPS	.6	.6	1.4	.3	.5	.8
SMALL BUSINESS ADMINISTRATION	.3	.2	.5	.4	.6	.3
SMITHSONIAN INSTITUTION	5.3	6.7	10.3	4.5	5.7	8.8
TENNESSEE VALLEY AUTHORITY	5.1	5.8	6.1	5.1	5.8	6.1
UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY	5.7	7.2	10.2	5.0	8.1	7.9
UNITED STATES INFORMATION AGENCY	.6	.4	.2	.6	.7	.2
VETERANS ADMINISTRATION	33.7	37.8	40.9	32.3	39.6	39.9

TABLE C-4. FEDERAL OBLIGATIONS FOR TOTAL RESEARCH AND DEVELOPMENT, BY AGENCY AND CHARACTER OF WORK
FISCAL YEAR 1964

-THOUSANDS OF DOLLARS-

AGENCY AND SUBDIVISION	TOTAL	RESEARCH		DEVELOPMENT
		BASIC	APPLIED	
TOTAL, ALL AGENCIES	14,132,865	1,573,903	2,967,223	9,591,739
DEPARTMENTS				
DEPARTMENT OF AGRICULTURE, TOTAL	189,034	67,989	113,805	7,240
AGRICULTURAL RESEARCH SERVICE	111,527	46,311	59,118	6,098
COOPERATIVE STATE RESEARCH SERVICE	42,821	13,896	28,925	.....
ECONOMIC RESEARCH SERVICE	8,996	1,529	7,467	.....
FARMER COOPERATIVE SERVICE	698	84	614	.....
FOREST SERVICE	24,432	6,108	17,347	977
NATIONAL AGRICULTURAL LIBRARY	19	.....	19	.....
STATISTICAL REPORTING SERVICE	541	61	315	165
DEPARTMENT OF COMMERCE, TOTAL	53,828	22,845	16,435	14,548
AREA REDEVELOPMENT ADMINISTRATION	1,058	.....	301	757
BUREAU OF THE CENSUS	1,804	149	782	873
BUREAU OF PUBLIC ROADS	4,511	200	3,598	713
COAST AND GEODETIC SURVEY	2,348	354	1,432	562
MARITIME ADMINISTRATION	5,187	450	600	4,137
NATIONAL BUREAU OF STANDARDS	25,558	16,431	4,897	4,230
OFFICE OF BUSINESS ECONOMICS	2,128	2,128	.....	.....
PATENT OFFICE	625	100	275	250
TRANSPORTATION RESEARCH	1,151	.....	1,151	.....
WEATHER BUREAU	9,458	3,033	3,399	3,026
DEPARTMENT OF DEFENSE, TOTAL	7,261,867	259,804	1,511,277	5,490,786
DEPARTMENT OF THE ARMY, TOTAL	1,376,947	51,156	252,934	1,072,857
RDT&E APPROPRIATIONS	1,321,020	48,381	240,033	1,032,606
CIVIL FUNCTIONS	4,037	188	1,705	2,144
DT&E SUPPORT FROM PROCUREMENT APPROPRIATIONS	6,090	304	1,315	4,471
PAY AND ALLOWANCES OF MILITARY PERSONNEL IN R&D	45,800	2,283	9,881	33,636
DEPARTMENT OF THE NAVY, TOTAL	1,621,225	91,061	257,457	1,272,707
RDT&E APPROPRIATIONS	1,492,154	84,622	229,582	1,177,950
DT&E SUPPORT FROM PROCUREMENT APPROPRIATIONS	42,840	2,136	9,250	31,454
DT&E SUPPORT FROM OPERATIONS AND MAINTENANCE APPROPRIATIONS	26,031	1,298	5,620	19,113
PAY AND ALLOWANCES OF MILITARY PERSONNEL IN R&D	60,200	3,005	13,005	44,190
DEPARTMENT OF THE AIR FORCE, TOTAL	3,784,019	83,587	612,634	3,087,798
RDT&E APPROPRIATIONS	3,591,880	74,000	571,141	2,946,739
DT&E SUPPORT FROM PROCUREMENT APPROPRIATIONS	21,070	1,050	4,550	15,470
DT&E SUPPORT FROM OPERATIONS AND MAINTENANCE APPROPRIATIONS	14,069	702	3,040	10,327
PAY AND ALLOWANCES OF MILITARY PERSONNEL IN R&D	157,000	7,835	33,903	115,262
DEFENSE AGENCIES, TOTAL	467,877	34,000	376,453	57,424
RDT&E APPROPRIATIONS	467,877	34,000	376,453	57,424
DEPARTMENTWIDE FUNDS	11,799	.....	11,799	.....
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	776,947	274,447	497,095	5,405
FOOD AND DRUG ADMINISTRATION	6,039	1,130	4,332	577
OFFICE OF EDUCATION	18,253	6,600	11,653	.....
PUBLIC HEALTH SERVICE	721,994	266,512	452,307	3,175
NATIONAL INSTITUTES OF HEALTH	/651,010/	/250,639/	/400,371/	/...../
SAINT ELIZABETHS HOSPITAL	282	71	211	.....
SOCIAL SECURITY ADMINISTRATION	2,161	134	2,027	.....
VOCATIONAL REHABILITATION ADMINISTRATION	20,367	.....	18,714	1,653
WELFARE ADMINISTRATION	7,851	.....	7,851	.....

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TABLE C-46. *Federal expenditures for research, development, and R&D plant, by agency, fiscal years 1940–66*

[Millions of dollars]

Agency	1940	1941	1942	1943	1944	1945	1946	1947	1948
TOTAL, ALL AGENCIES	74.1	197.9	280.3	602.4	1,377.2	1,590.7	917.8	899.9	854.8
Departments									
DEPARTMENT OF AGRICULTURE	29.1	28.3	29.9	30.7	32.1	33.7	36.8	39.2	42.4
DEPARTMENT OF COMMERCE	3.3	3.1	3.2	5.2	5.2	5.0	5.0	4.8	8.2
DEPARTMENT OF DEFENSE, TOTAL	26.4	143.7	211.1	395.1	448.1	513.0	418.0	550.8	592.2
DEPARTMENT OF THE ARMY [a]	3.8	18.7	68.4	149.0	161.3	134.0	114.0	100.0	116.4
DEPARTMENT OF THE NAVY [a]	13.9	24.6	58.9	130.5	176.6	243.0	183.0	293.8	287.5
DEPARTMENT OF THE AIR FORCE [a]	8.7	100.4	83.8	115.6	110.2	136.0	121.0	157.0	188.3
ADVANCED RESEARCH PROJECTS AGENCY [b]	......	......	......	......	......	......	......	......	......
DEPARTMENTWIDE FUNDS [b]	......	......	......	......	......	......	......	......	......
DEFENSE AGENCIES [b]	......	......	......	......	......	......	......	......	......
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE [c]	2.8	3.0	3.2	3.2	3.3	3.4	3.5	10.1	22.8
DEPARTMENT OF THE INTERIOR	7.9	9.5	13.5	17.0	20.7	18.0	17.0	20.3	31.4
Other Agencies									
ATOMIC ENERGY COMMISSION	......	......	......	......	......	......	......	37.7	107.5
FEDERAL AVIATION AGENCY	......	......	......	......	......	......	......	......	......
MANHATTAN ENGINEER DISTRICT [d]	......	......	......	77.0	730.0	859.0	366.0	186.0	......
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION [e]	2.2	2.6	5.0	9.8	18.4	24.1	23.7	35.2	37.5
NATIONAL SCIENCE FOUNDATION	......	......	......	......	......	......	......	......	......
OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT	......	5.3	11.0	52.2	86.8	114.5	36.8	5.6	.9
VETERANS ADMINISTRATION	......	......	......	......	......	......	......	......	......
ALL OTHER AGENCIES	2.4	2.4	3.4	12.2	32.6	20.0	11.0	10.2	11.8

Agency	1949	1950	1951	1952	1953	1954	1955	1956	1957
TOTAL, ALL AGENCIES	1,082.0	1,082.8	1,300.5	1,816.2	3,101.0	3,147.9	3,308.3	3,446.0	4,461.9
Departments									
DEPARTMENT OF AGRICULTURE	50.5	53.0	52.4	57.1	54.9	55.4	72.0	87.7	97.0
DEPARTMENT OF COMMERCE	12.5	12.0	16.9	10.1	13.6	10.6	9.9	20.4	19.8
DEPARTMENT OF DEFENSE, TOTAL	695.4	652.3	823.4	1,317.0	2,454.8	2,487.2	2,630.2	2,639.0	3,371.4
DEPARTMENT OF THE ARMY [a]	136.6	123.1	161.6	318.0	743.3	815.7	1,012.8	702.4	782.1
DEPARTMENT OF THE NAVY [a]	332.9	310.8	363.8	476.0	678.3	664.7	591.9	635.8	784.9
DEPARTMENT OF THE AIR FORCE [a]	225.9	218.4	297.9	523.0	1,033.2	1,006.8	982.2	1,278.9	1,780.0
ADVANCED RESEARCH PROJECTS AGENCY [b]	......	......	......	......	......	......	......	......	......
DEPARTMENT WIDE FUNDS [b]	......	......	......	......	......	......	43.3	21.9	24.4
DEFENSE AGENCIES [b]	......	......	......	......	......	......	......	......	......
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE [c]	27.9	39.6	53.4	64.1	65.2	62.5	70.2	86.2	143.5
DEPARTMENT OF THE INTERIOR	38.2	32.1	32.1	32.8	35.2	39.1	31.9	35.7	42.3
Other Agencies									
ATOMIC ENERGY COMMISSION	196.1	221.4	242.6	249.6	378.1	383.1	385.4	474.0	656.5
FEDERAL AVIATION AGENCY	......	......	......	......	......	......	......	......	......
MANHATTAN ENGINEER DISTRICT [d]	......	......	......	......	......	......	......	......	......
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION [e]	48.7	54.5	61.6	67.4	78.6	89.5	73.8	71.1	76.1
NATIONAL SCIENCE FOUNDATION	......	......	.1	.5	2.1	3.6	8.5	15.4	30.6
OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT	......	......	......	......	......	......	......	......	......
VETERANS ADMINISTRATION	......	......	......	3.3	4.6	5.1	5.3	6.1	9.4
ALL OTHER AGENCIES	12.8	17.7	18.2	14.3	13.9	11.8	21.1	10.4	15.3

See footnotes at end of table.

Table C–46. *Federal expenditures for research, development, and R&D plant, by agency, fiscal years 1940–66*—Continued

(Millions of dollars)

Agency	1958	1959	1960	1961	1962	1963	1964	Estimates 1965	Estimates 1966
TOTAL, ALL AGENCIES	4,989.9	5,802.9	7,738.0	9,278.1	10,373.3	11,988.3	14,693.9	15,371.5	15,437.7
Departments									
Department of Agriculture	111.8	124.7	131.4	147.7	155.7	172.5	183.4	231.3	257.7
Department of Commerce	17.8	30.1	33.1	35.5	47.5	70.4	84.5	98.0	93.0
Department of Defense, total	3,664.2	4,183.3	5,653.8	6,618.1	6,812.0	6,848.8	7,517.0	7,222.3	6,880.7
Department of the Army [a]	873.5	890.9	1,108.9	1,306.0	1,243.5	1,421.2	1,413.6	1,482.3	1,452.1
Department of the Navy [a]	854.1	1,034.7	1,300.6	1,631.0	1,561.0	1,573.6	1,724.2	1,590.0	1,540.0
Department of the Air Force [a]	1,894.0	2,134.5	2,978.0	3,440.6	3,672.9	3,539.1	3,951.1	3,616.6	3,384.4
Advanced Research Projects Agency [a]	3.0	80.9	226.3	206.6	192.9	....	....	....	....
Departmentwide funds [b]	39.6	42.3	40.0	33.9	141.7	14.6	21.1	45.7	39.7
Defense agencies [b]	....	....	....	....	....	300.4	406.9	487.7	464.5
Department of Health, Education, and Welfare [c]	180.3	252.8	324.2	374.1	512.1	632.4	793.4	812.9	963.9
Department of the Interior	48.9	72.2	65.3	75.1	86.7	102.7	102.0	126.7	138.7
Other Agencies									
Atomic Energy Commission	804.2	877.1	985.9	1,111.1	1,284.3	1,335.6	1,505.0	1,571.6	1,559.7
Federal Aviation Agency	4.2	27.6	41.2	52.9	53.7	74.7	74.0	108.6	73.4
Manhattan Engineer District [d]	....	....	....	....	....	....	....	....	....
National Aeronautics and Space Administration [e]	89.2	145.5	401.0	741.6	1,251.3	2,539.5	4,171.0	4,900.0	5,100.0
National Science Foundation	33.0	50.6	58.0	76.5	104.8	142.1	189.8	201.4	258.7
Office of Scientific Research and Development	....	....	....	....	....	....	....	....	....
Veterans Administration	12.8	16.8	18.6	23.1	30.8	33.1	34.1	41.3	45.9
All Other Agencies	23.5	22.2	25.4	22.6	34.3	36.5	39.7	57.5	66.1

[a] Includes pay and allowances of military R&D personnel beginning in fiscal year 1953, and support from procurement appropriations of development, test, and evaluation, starting with fiscal year 1954.

[b] Starting with 1963, Defense agencies include the Advanced Research Projects Agency (ARPA), and other agencies such as Defense Atomic Support Agency and Defense Communications Agency. With the exception of ARPA, these agencies were previously included in departmentwide funds.

Starting with 1963, departmentwide funds include Military Assistance, Civil Defense and Emergency Funds only.

[c] Federal Security Agency prior to fiscal year 1952.

[d] This agency, under the Department of War, is shown separately to identify funds for this atomic energy project from other R&D funds.

[e] National Advisory Committee for Aeronautics prior to fiscal year 1958.

Sources: National Science Foundation and Bureau of the Budget (prior to 1952).

TABLE C-49. *Federal obligations for research and development, by character of work and R&D plant, fiscal years 1956-66*

[Millions of dollars]

Fiscal years	Total	Research		Development	R&D plant
		Basic	Applied		
1956	$3,267	$208	$681	$2,099	$279
1957	4,389	264	699	2,968	457
1958	4,905	336	780	3,452	336
1959	7,116	519	928	5,240	429
1960	8,074	612	1,367	5,567	528
1961	9,601	827	1,838	6,388	548
1962	11,060	1,110	2,212	6,960	778
1963	13,650	1,395	2,696	8,373	1,186
1964	15,310	1,574	2,967	9,592	1,178
1965 (estimate)	16,488	1,808	3,249	9,772	1,659
1966 (estimate)	16,146	2,049	3,558	9,673	865

TABLE C-50. *Federal obligations for total research, by selected agency, fiscal years 1956-66*

[Millions of dollars]

Agency	1956	1957	1958	1959	1960	1961	1962	1963	1964	Estimates	
										1965	1966
TOTAL	890	964	1,116	1,447	1,979	2,665	3,323	4,091	4,541	5,057	5,607
Department of Agriculture	83	95	105	116	121	138	150	160	182	219	224
Department of Defense [a]	520	485	527	568	900	1,217	1,360	1,652	1,771	1,863	2,116
Department of Health, Education, and Welfare	83	142	182	240	317	427	574	653	772	873	970
Atomic Energy Commission	87	99	131	170	199	220	247	281	308	336	369
National Aeronautics and Space Administration [b]	43	47	66	201	264	453	714	1,005	1,147	1,338	1,399
National Science Foundation	16	30	33	54	68	77	105	144	164	198	270
All others	59	66	72	98	110	132	172	195	197	230	257

[a] Includes pay and allowances of military R&D personnel and support from the procurement and operation and maintenance appropriations.

[b] National Advisory Committee for Aeronautics prior to 1958.

Table C–51. *Federal obligations for basic research, by selected agency, fiscal years 1952–66*

[Millions of dollars]

Agency	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	Estimates 1965	Estimates 1966
TOTAL	162	154	148	162	208	264	336	519	612	827	1,110	1,395	1,574	1,808	2,049
Department of Defense [a]	72	65	52	53	80	86	113	139	170	175	206	234	260	293	324
Department of Health, Education, and Welfare	15	15	17	21	26	38	50	75	103	137	190	236	274	309	340
Atomic Energy Commission	34	35	40	42	45	55	72	87	104	167	192	219	238	260	289
National Aeronautics and Space Administration [b]	18	16	14	12	13	16	26	107	97	190	316	447	505	585	650
National Science Foundation	1	2	5	10	15	30	33	54	68	77	105	144	163	197	270
All others	21	20	20	24	29	39	43	57	69	80	100	115	134	163	177

[a] Includes pay and allowances of military personnel and support from procurement and operation and maintenance appropriations starting with fiscal year 1964 data.

[b] National Advisory Committee for Aeronautics prior to 1958.

Table C–52. *Federal obligations for applied research, by selected agency, fiscal years 1956–66*

[Millions of dollars]

Agency	1956	1957	1958	1959	1960	1961	1962	1963	1964	Estimates 1965	Estimates 1966
TOTAL	681	699	780	928	1,367	1,838	2,212	2,696	2,967	3,249	3,558
Department of Agriculture	68	76	81	87	87	97	101	104	114	133	135
Department of Defense [a]	439	399	414	429	729	1,042	1,153	1,419	1,511	1,569	1,792
Department of Health, Education, and Welfare	57	104	133	165	214	291	384	416	497	563	630
Atomic Energy Commission	42	44	59	83	95	53	55	62	71	76	80
National Aeronautics and Space Administration [b]	29	31	41	95	166	263	398	558	642	754	749
All others	46	46	52	71	75	92	121	137	132	154	170

[a] Includes pay and allowances of military personnel and support from the procurement and operation and maintenance appropriations.

[b] National Advisory Committee for Aeronautics prior to 1958.

Table C–53. *Federal obligations for development, by selected agency, fiscal years 1956–66*

[Billions of dollars]

Agency	1956	1957	1958	1959	1960	1961	1962	1963	1964	Estimates 1965	Estimates 1966
TOTAL	2.1	3.0	3.5	5.2	5.6	6.4	7.0	8.4	9.6	9.8	9.7
Department of Defense [a]	1.7	2.5	2.9	4.6	4.8	5.4	5.4	5.6	5.5	5.1	5.0
Atomic Energy Commission	.3	.4	.5	.5	.6	.6	.8	.8	.9	.9	.9
National Aeronautics and Space Administration [b]	(c)	(c)	(c)	.1	.1	.3	.7	1.8	3.1	3.5	3.6
All other	(c)	(c)	.1	.1	.1	.1	.1	.1	.1	.2	.2

[a] Includes pay and allowances of military personnel and support from the procurement and operation and maintenance appropriations.

[b] National Advisory Committee for Aeronautics prior to 1958.

[c] Less than $50 million.

APPENDIX B

Federal Funds for Scientific and Technical Information

This Appendix reproduces statistics on Federal Government expenditures for scientific and technical information and data, as compiled by the National Science Foundation.

It must be recognized that the funding totals mentioned here significantly understate the total expenditures of the Federal Government for these purposes.

TABLE E-1. *Summary of Federal obligations for collection of general-purpose scientific data, fiscal years 1964, 1965, and 1966*

[Thousands of dollars]

Performer and activity	Actual 1964			Estimates					
				1965			1966		
	Total	Natural phenomena	Social phenomena	Total	Natural phenomena	Social phenomena	Total	Natural phenomena	Social phenomena
TOTAL OBLIGATIONS FOR COLLECTION OF GENERAL-PURPOSE SCIENTIFIC DATA	309,075	226,964	82,111	346,852	248,251	98,601	354,008	255,122	98,886
BY PERFORMER:									
Intramural	295,645	217,382	78,263	332,600	238,512	94,088	340,275	246,046	94,229
Extramural	13,430	9,582	3,848	14,252	9,739	4,513	13,733	9,076	4,657
BY ACTIVITY:									
Gathering, processing, and collating	180,127	121,418	58,709	202,928	125,504	77,424	206,177	131,708	74,469
Analysis	29,850	21,518	8,332	32,498	23,504	8,994	35,788	25,711	10,077
Publications	39,623	37,148	2,475	44,563	41,762	2,801	50,195	47,034	3,161
Equipment for data gathering, processing, or collating	53,682	46,880	6,802	60,284	57,481	2,803	55,269	50,669	4,600

TABLE E-2. *Federal obligations for collection of general-purpose scientific data, by agency, fiscal years 1964, 1965, and 1966*

[Thousands of dollars]

Agency and subdivision	Actual 1964	Estimates	
		1965	1966
TOTAL, ALL AGENCIES	309,075	346,852	354,008
Departments			
DEPARTMENT OF AGRICULTURE, TOTAL	35,876	38,394	41,210
Agricultural Stabilization and Conservation Service	22	32	23
Consumer and Marketing Service	5,793	6,579	6,579
Farmer Cooperative Service	48	50	50
Soil Conservation Service	20,026	20,485	20,767
Statistical Reporting Service	9,987	11,248	13,791
DEPARTMENT OF COMMERCE, TOTAL	145,714	166,029	161,754
Area Redevelopment Administration	16	15	15
Bureau of the Census	25,807	37,324	30,747
Coast and Geodetic Survey	20,060	22,353	25,711
Weather Bureau	99,831	106,337	105,281
DEPARTMENT OF DEFENSE, TOTAL	38,826	49,764	54,379
DEPARTMENT OF THE ARMY—CIVIL FUNCTIONS	2,217	2,781	3,265
DEPARTMENT OF THE NAVY	36,609	46,983	51,114
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	11,219	12,318	13,745
Office of Education	1,125	1,425	1,950
Public Health Service	8,899	9,577	10,454
National Institutes of Health	(938)	(972)	(976)
Social Security Administration	932	1,016	1,034
Welfare Administration	263	300	307
DEPARTMENT OF THE INTERIOR, TOTAL	40,161	42,748	44,014
Bureau of Commercial Fisheries	1,360	1,440	1,420
Bureau of Land Management	29	29	29
Bureau of Mines	2,165	2,285	2,555
Bureau of Sport Fisheries and Wildlife	4,068	4,274	4,651
Geological Survey	32,539	34,720	35,359
DEPARTMENT OF JUSTICE, TOTAL	639	706	716
Federal Bureau of Investigation	421	481	486
Immigration and Naturalization Service	218	225	230
DEPARTMENT OF LABOR, TOTAL	15,241	15,958	17,240
Bureau of Employment Security	122	125	150
Bureau of Labor Statistics	15,119	15,833	17,090
DEPARTMENT OF STATE, TOTAL	7,679	6,449	4,742
Agency for International Development	7,597	6,350	4,643
Departmental funds	82	99	99
DEPARTMENT OF THE TREASURY, TOTAL	8,468	8,603	8,740
Internal Revenue Service	4,175	4,310	4,445
United States Coast Guard	4,293	4,293	4,295
Other Agencies			
FEDERAL AVIATION AGENCY	835	894	899
FEDERAL COMMUNICATIONS COMMISSION	17	18	20
FEDERAL HOME LOAN BANK BOARD	652	766	909
FEDERAL POWER COMMISSION	806	882	882
FEDERAL TRADE COMMISSION	265	293	293
HOUSING AND HOME FINANCE AGENCY	235	230	1,190
NATIONAL SCIENCE FOUNDATION	1,817	2,036	2,372
SECURITIES AND EXCHANGE COMMISSION	330	357	391
TENNESSEE VALLEY AUTHORITY	208	300	401
UNITED STATES TARIFF COMMISSION	78	98	102
VETERANS ADMINISTRATION	9	9	9

TABLE E-3. *Federal obligations for collection of general-purpose scientific data, by agency, phenomena, and activity, fiscal year 1964*

[Thousands of dollars]

Agency and subdivision	Natural phenomena: Total	Natural phenomena: Gathering, processing, and collating	Natural phenomena: Analysis	Natural phenomena: Publication	Natural phenomena: Equipment for data gathering, processing, and collating	Social phenomena: Total	Social phenomena: Gathering, processing, and collating	Social phenomena: Analysis	Social phenomena: Publication	Social phenomena: Equipment for data gathering, processing, and collating
TOTAL, ALL AGENCIES	226,964	121,418	21,518	37,148	46,880	82,111	58,709	8,332	2,475	6,802
Departments										
DEPARTMENT OF AGRICULTURE, TOTAL	20,026	17,574	563	1,781	108	15,850	7,048	2,275	499	235
Agricultural Stabilization and Conservation Service	...	...	...	...	...	22	3	9	9	1
Consumer and Marketing Service	...	...	...	...	...	5,793	...	...	...	...
Farmer Cooperative Service	...	...	...	...	...	48	22	22	2	2
Soil Conservation Service	20,026	17,574	563	1,781	108	...	...	...	...	...
Statistical Reporting Service	...	...	...	...	...	9,987	7,023	2,244	488	232
DEPARTMENT OF COMMERCE, TOTAL	119,891	53,288	15,792	18,159	32,652	25,823	20,178	352	335	4,958
Area Redevelopment Administration	...	...	...	...	...	16	16	...	...	...
Bureau of the Census	...	...	...	...	...	25,807	20,162	352	335	4,958
Coast and Geodetic Survey	20,060	14,233	745	3,039	2,043	...	...	...	...	...
Weather Bureau	99,831	39,055	15,047	15,120	30,609	...	...	...	...	...
DEPARTMENT OF DEFENSE, TOTAL	37,847	11,508	1,177	13,306	11,856	979	734	98	78	69
DEPARTMENT OF THE ARMY—CIVIL FUNCTIONS	1,238	904	124	123	87	979	734	98	78	69
DEPARTMENT OF THE NAVY	36,609	10,604	1,053	13,183	11,769	...	...	...	...	...
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	1,954	1,458	171	225	100	9,265	7,423	1,091	381	370
Office of Education	...	...	...	...	...	1,125	810	152	51	112
Public Health Service	1,954	1,458	171	225	100	6,945	5,587	817	296	245
National Institutes of Health	...	...	...	...	...	(938)	(640)	(278)	(20)	...
Social Security Administration	...	...	...	...	...	932	916	...	3	13
Welfare Administration	...	...	...	...	...	263	110	122	31	...
DEPARTMENT OF THE INTERIOR, TOTAL	36,636	27,124	3,765	3,583	2,164	3,525	2,829	298	328	70
Bureau of Commercial Fisheries	...	...	...	...	...	1,360	1,076	36	223	25
Bureau of Land Management	29	25	...	4	...	...	...	...	...	...
Bureau of Mines	...	...	...	...	...	2,165	1,753	262	105	45
Bureau of Sport Fisheries and Wildlife	4,068	3,456	400	173	39	...	...	...	...	...
Geological Survey	32,539	23,643	3,365	3,406	2,125	...	...	...	...	...
DEPARTMENT OF JUSTICE, TOTAL	...	...	...	...	...	639	438	75	54	72
Federal Bureau of Investigation	...	...	...	...	...	421	250	60	53	58
Immigration and Naturalization Service	...	...	...	...	...	218	188	15	1	14
DEPARTMENT OF LABOR, TOTAL	...	...	...	...	...	15,241	11,360	2,846	457	578
Bureau of Employment Security	...	...	...	...	...	122	88	22	12	...
Bureau of Labor Statistics	...	...	...	...	...	15,119	11,272	2,824	445	578
DEPARTMENT OF STATE, TOTAL	6,109	6,109	...	...	...	1,570	1,555	...	15	...
Agency for International Development	6,109	6,109	...	...	...	1,488	1,488	...	...	...
Departmental funds	...	...	...	...	...	82	67	...	15	...
DEPARTMENT OF THE TREASURY, TOTAL	4,293	4,290	...	3	...	4,175	3,200	475	100	400
Internal Revenue Service	...	...	...	...	...	4,175	3,200	475	100	400
United States Coast Guard	4,293	4,290	...	3	...	...	...	...	...	...
Other Agencies										
FEDERAL AVIATION AGENCY	...	...	...	...	...	835	774	23	25	13
FEDERAL COMMUNICATIONS COMMISSION	...	...	...	...	...	17	13	2	2	...
FEDERAL HOME LOAN BANK BOARD	...	...	...	...	...	652	475	119	58	...
FEDERAL POWER COMMISSION	...	...	...	...	...	806	494	211	79	22
FEDERAL TRADE COMMISSION	...	...	...	...	...	265	258	3	4	...
HOUSING AND HOME FINANCE AGENCY	...	...	...	...	...	235	235	...	...	...
NATIONAL SCIENCE FOUNDATION	...	...	...	...	...	1,817	1,346	428	41	2
SECURITIES AND EXCHANGE COMMISSION	...	...	...	...	...	330	310	...	7	13
TENNESSEE VALLEY AUTHORITY	208	67	50	91	...	...	...	...	...	...
UNITED STATES TARIFF COMMISSION	...	...	...	...	...	78	36	30	12	...
VETERANS ADMINISTRATION	...	...	...	...	...	9	3	6	...	...

TABLE E-4. *Federal obligations for collection of general-purpose scientific data, by agency, phenomena, and activity, fiscal year 1965 (estimated)*

[Thousands of dollars]

Agency and subdivision	Natural phenomena: Total	Natural phenomena: Gathering, processing, and collating	Natural phenomena: Analysis	Natural phenomena: Publication	Natural phenomena: Equipment for data gathering, processing, and collating	Social phenomena: Total	Social phenomena: Gathering, processing, and collating	Social phenomena: Analysis	Social phenomena: Publication	Social phenomena: Equipment for data gathering, processing, and collating
TOTAL, ALL AGENCIES	248, 251	125, 504	23, 504	41, 762	57, 481	98, 601	77, 424	8, 994	2, 801	2, 803
Departments										
DEPARTMENT OF AGRICULTURE, TOTAL	20, 485	17, 704	662	2, 011	108	17, 909	7, 857	2, 539	557	377
Agricultural Stabilization and Conservation Service						32	6	15	11	
Consumer and Marketing Service						6, 579				
Farmer Cooperative Service						50	23	23	2	2
Soil Conservation Service										
Statistical Reporting Service	20, 485	17, 704	662	2, 011	108	11, 248	7, 828	2, 501	544	375
DEPARTMENT OF COMMERCE, TOTAL	128, 690	58, 202	17, 075	19, 238	34, 175	37, 339	35, 553	436	502	848
Area Redevelopment Administration						15	15			
Bureau of the Census						37, 324	35, 538	436	502	848
Coast and Geodetic Survey	22, 353	16, 208	762	3, 353	2, 030					
Weather Bureau	106, 337	41, 994	16, 313	15, 885	32, 145					
DEPARTMENT OF DEFENSE, TOTAL	48, 693	10, 034	1, 237	16, 289	21, 133	1, 071	803	107	86	75
DEPARTMENT OF THE ARMY—CIVIL FUNCTIONS	1, 710	1, 248	171	171	120	1, 071	803	107	86	75
DEPARTMENT OF THE NAVY	46, 983	8, 786	1, 066	16, 118	21, 013					
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	2, 139	1, 558	236	245	100	10, 179	8, 163	1, 174	426	416
Office of Education						1, 425	1, 026	192	64	143
Public Health Service	2, 139	1, 558	236	245	100	7, 438	6, 016	834	322	266
National Institutes of Health						(972)	(674)	(293)	(5)	
Social Security Administration						1, 016	1, 001		8	7
Welfare Administration						300	120	148	32	
DEPARTMENT OF THE INTERIOR, TOTAL	39, 023	28, 973	4, 236	3, 849	1, 965	3, 725	2, 998	322	339	66
Bureau of Commercial Fisheries						1, 440	1, 145	41	233	21
Bureau of Land Management	29	25		4						
Bureau of Mines						2, 285	1, 853	281	106	45
Bureau of Sport Fisheries and Wildlife	4, 274	3, 592	420	220	42					
Geological Survey	34, 720	25, 356	3, 816	3, 625	1, 923					
DEPARTMENT OF JUSTICE, TOTAL						706	480	85	60	81
Federal Bureau of Investigation						481	286	69	59	67
Immigration and Naturalization Service						225	194	16	1	14
DEPARTMENT OF LABOR, TOTAL						15, 958	12, 245	2, 788	447	478
Bureau of Employment Security						125	99	18	8	
Bureau of Labor Statistics						15, 833	12, 146	2, 770	439	478
DEPARTMENT OF STATE, TOTAL	4, 628	4, 628				1, 821	1, 791		30	
Agency for International Development	4, 628	4, 628				1, 722	1, 722			
Departmental funds						99	69		30	
DEPARTMENT OF THE TREASURY, TOTAL	4, 293	4, 290		3		4, 310	3, 300	500	110	400
Internal Revenue Service						4, 310	3, 300	500	110	400
United States Coast Guard	4, 293	4, 290		3						
Other Agencies										
FEDERAL AVIATION AGENCY						894	830	22	23	19
FEDERAL COMMUNICATIONS COMMISSION						18	14	2	2	
FEDERAL HOME LOAN BANK BOARD						766	559	139	68	
FEDERAL POWER COMMISSION						882	541	232	86	23
FEDERAL TRADE COMMISSION						293	285	4	4	
HOUSING AND HOME FINANCE AGENCY						230	230			
NATIONAL SCIENCE FOUNDATION						2, 036	1, 400	596	38	2
SECURITIES AND EXCHANGE COMMISSION						357	331		8	18
TENNESSEE VALLEY AUTHORITY	300	115	58	127						
UNITED STATES TARIFF COMMISSION						98	41	42	15	
VETERANS ADMINISTRATION						9	3	6		

Table E-5. *Federal obligations for collection of general-purpose scientific data, by agency, phenomena, and activity, fiscal year 1966 (estimated)*

[Thousands of dollars]

Agency and subdivision	Natural phenomena: Total	Natural phenomena: Gathering, processing, and collating	Natural phenomena: Analysis	Natural phenomena: Publication	Natural phenomena: Equipment for data gathering, processing, and collating	Social phenomena: Total	Social phenomena: Gathering, processing, and collating	Social phenomena: Analysis	Social phenomena: Publication	Social phenomena: Equipment for data gathering, processing, and collating
TOTAL, ALL AGENCIES	255,122	131,708	25,711	47,034	50,669	98,886	74,469	10,077	3,161	4,600
Departments										
DEPARTMENT OF AGRICULTURE, TOTAL	20,767	17,234	743	2,682	108	20,443	8,502	2,740	598	2,024
Agricultural Stabilization and Conservation Service						23	5	10	8	
Consumer and Marketing Service						6,579				
Farmer Cooperative Service						50	23	23	2	2
Soil Conservation Service	20,767	17,234	743	2,682	108					
Statistical Reporting Service						13,791	8,474	2,707	588	2,022
DEPARTMENT OF COMMERCE, TOTAL	130,992	60,909	18,145	20,058	31,880	30,762	28,553	652	694	863
Area Redevelopment Administration						15	15			
Bureau of the Census						30,747	28,538	652	694	863
Coast and Geodetic Survey	25,711	18,701	918	3,462	2,630					
Weather Bureau	105,281	42,208	17,227	16,596	29,250					
DEPARTMENT OF DEFENSE, TOTAL	53,249	15,035	1,884	19,790	16,540	1,130	848	113	90	79
DEPARTMENT OF THE ARMY—CIVIL FUNCTIONS	2,135	1,559	214	213	149	1,130	848	113	90	79
DEPARTMENT OF THE NAVY	51,114	13,476	1,670	19,577	16,391					
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	2,262	1,591	302	269	100	11,483	9,170	1,317	478	518
Office of Education						1,950	1,404	263	88	195
Public Health Service	2,262	1,591	302	269	100	8,192	6,619	902	353	318
National Institutes of Health						(976)	(679)	(292)	(5)	
Social Security Administration						1,034	1,024		5	5
Welfare Administration						307	123	152	32	
DEPARTMENT OF THE INTERIOR, TOTAL	40,039	29,348	4,572	4,078	2,041	3,975	3,225	326	343	81
Bureau of Commercial Fisheries						1,420	1,125	41	233	21
Bureau of Land Management	29	25		4						
Bureau of Mines						2,555	2,100	285	110	60
Bureau of Sport Fisheries and Wildlife	4,651	3,617	640	330	64					
Geological Survey	35,359	25,706	3,932	3,744	1,977					
DEPARTMENT OF JUSTICE, TOTAL						716	489	86	60	81
Federal Bureau of Investigation						486	290	70	59	67
Immigration and Naturalization Service						230	199	16	1	14
DEPARTMENT OF LABOR, TOTAL						17,240	13,241	3,035	478	486
Bureau of Employment Security						150	122	19	9	
Bureau of Labor Statistics						17,090	13,119	3,016	469	486
DEPARTMENT OF STATE, TOTAL	3,117	3,117				1,625	1,595		30	
Agency for International Development	3,117	3,117				1,526	1,526			
Departmental funds						99	69		30	
DEPARTMENT OF THE TREASURY, TOTAL	4,295	4,290		5		4,445	3,400	525	120	400
Internal Revenue Service						4,445	3,400	525	120	400
United States Coast Guard	4,295	4,290		5						
Other Agencies										
FEDERAL AVIATION AGENCY						899	840	23	22	14
FEDERAL COMMUNICATIONS COMMISSION						20	16	2	2	
FEDERAL HOME LOAN BANK BOARD						909	663	165	81	
FEDERAL POWER COMMISSION						882	541	232	86	23
FEDERAL TRADE COMMISSION						293	285	4	4	
HOUSING AND HOME FINANCE AGENCY						1,190	1,190			
NATIONAL SCIENCE FOUNDATION						2,372	1,512	808	50	2
SECURITIES AND EXCHANGE COMMISSION						391	354		8	29
TENNESSEE VALLEY AUTHORITY	401	184	65	152						
UNITED STATES TARIFF COMMISSION						102	42	43	17	
VETERANS ADMINISTRATION						9	3	6		

TABLE E-6. *Federal extramural obligations for collection of general-purpose scientific data, by agency, fiscal years 1964, 1965, and 1966*

[Thousands of dollars]

Agency and subdivision	Natural phenomena			Social phenomena		
	Actual 1964	Estimates		Actual 1964	Estimates	
		1965	1966		1965	1966
TOTAL, ALL AGENCIES	9,582	9,739	9,076	3,848	4,513	4,657
Departments						
DEPARTMENT OF AGRICULTURE, TOTAL	273	290	280	....	....	....
Soil Conservation Service	273	290	280	....	....	....
DEPARTMENT OF COMMERCE, TOTAL	2,642	2,479	3,419	186	107	115
Area Redevelopment Administration	....	....	....	....	....	....
Bureau of the Census	....	....	....	186	107	115
Weather Bureau	2,642	2,479	3,419	....	....	....
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	29	12	13	1,313	1,437	1,452
Public Health Service	29	12	13	1,313	1,437	1,452
National Institutes of Health	....	....	....	(95)	(137)	(200)
DEPARTMENT OF THE INTERIOR, TOTAL	3,995	4,194	4,411	....	....	....
Bureau of Sport Fisheries and Wildlife	3,995	4,194	4,411	....	....	....
DEPARTMENT OF JUSTICE, TOTAL	....	....	....	24	23	23
Immigration and Naturalization Service	....	....	....	24	23	23
DEPARTMENT OF LABOR, TOTAL	....	....	....	33	40	74
Bureau of Employment Security	....	....	....	33	40	74
DEPARTMENT OF STATE, TOTAL	2,643	2,764	953	1,311	1,632	1,456
Agency for International Development	2,643	2,764	953	1,311	1,632	1,456
Other Agencies						
FEDERAL AVIATION AGENCY	....	....	....	4	4	4
FEDERAL TRADE COMMISSION	....	....	....	3	3	3
HOUSING AND HOME FINANCE AGENCY	....	....	....	....	....	100
NATIONAL SCIENCE FOUNDATION	....	....	....	974	1,267	1,430

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TABLE D-1. *Summary of Federal obligations for scientific and technical information, fiscal years 1964, 1965, and 1966*

[Thousands of dollars]

Activity	Actual 1964			Estimates					
				1965			1966		
	Total	Intra-mural	Extra-mural	Total	Intra-mural	Extra-mural	Total	Intra-mural	Extra-mural
TOTAL OBLIGATIONS FOR SCIENTIFIC AND TECHNICAL INFORMATION	203,194	142,745	60,449	222,848	158,995	63,853	258,673	181,804	76,869
PUBLICATION AND DISTRIBUTION	59,858	44,347	15,511	66,806	48,393	18,413	71,518	49,974	21,544
Publication and distribution	57,984	43,938	14,046	64,090	47,919	16,171	69,071	49,447	19,624
Support of publications	1,874	409	1,465	2,716	474	2,242	2,447	527	1,920
DOCUMENTATION, REFERENCE AND INFORMATION SERVICES	90,803	65,465	25,338	101,226	74,246	26,980	120,169	90,230	29,939
Bibliographic and reference services	76,313	59,428	16,885	85,309	67,230	18,079	101,340	80,110	21,230
Specialized information centers	10,545	5,611	4,934	11,866	6,535	5,331	15,169	9,510	5,659
Translations	3,945	426	3,519	4,051	481	3,570	3,660	610	3,050
SYMPOSIA AND AUDIO/VISUAL MEDIA	22,665	14,052	8,613	23,726	15,432	8,294	25,478	15,869	9,609
Symposia and technical meetings	13,880	6,865	7,015	15,001	8,241	6,760	16,014	8,036	7,978
Audio/visual media and other forms of oral communication	8,785	7,187	1,598	8,725	7,191	1,534	9,464	7,833	1,631
RESEARCH AND DEVELOPMENT IN INFORMATION SCIENCES, DOCUMENTATION AND INFORMATION SYSTEMS, TECHNIQUES AND DEVICES	12,628	3,839	8,789	11,927	4,155	7,772	18,326	7,378	10,948
MANAGEMENT AND ADMINISTRATION—INFORMATION PROGRAMS AND SERVICES	17,240	15,042	2,198	19,163	16,769	2,394	23,182	18,353	4,829

TABLE D-2. *Federal obligations for scientific and technical information, by agency, fiscal years 1964, 1965, and 1966*

[Thousands of dollars]

Agency and subdivision	Actual 1964	Estimates 1965	Estimates 1966
TOTAL, ALL AGENCIES	203,194	222,848	258,673
Departments			
DEPARTMENT OF AGRICULTURE, TOTAL	5,230	5,777	13,156
Agricultural Research Service	1,460	1,686	1,828
Cooperative State Research Service	84	64	62
Economic Research Service	245	253	229
Farmer Cooperative Service	105	112	122
Forest Service	1,581	1,847	1,939
National Agricultural Library	1,652	1,711	8,868
Soil Conservation Service	94	94	94
Statistical Reporting Service	9	10	14
DEPARTMENT OF COMMERCE, TOTAL	32,612	37,098	41,090
Bureau of the Census	211	232	206
Bureau of Public Roads	418	467	500
Coast and Geodetic Survey	95	205	185
Maritime Administration	23	3	5
National Bureau of Standards	4,637	5,387	7,130
Office of Business Economics	90	95	100
Patent Office	26,750	30,180	32,360
Weather Bureau	388	529	604
DEPARTMENT OF DEFENSE, TOTAL	83,652	92,797	99,628
DEPARTMENT OF THE ARMY	49,723	52,209	54,819
DEPARTMENT OF THE NAVY	14,361	15,398	13,319
DEPARTMENT OF THE AIR FORCE	12,357	13,927	20,253
DEFENSE AGENCIES	7,211	11,263	11,237
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	24,263	24,345	31,208
Food and Drug Administration	367	445	2,340
Office of Education	562	700	739
Public Health Service	22,917	22,709	27,611
National Institutes of Health	(13,691)	(14,224)	(17,587)
National Library of Medicine	(4,595)	(4,554)	(5,484)
Saint Elizabeths Hospital	3	5	6
Social Security Administration	148	181	200
Vocational Rehabilitation Administration	160	212	217
Welfare Administration	106	93	95

TABLE D-2. *Federal obligations for scientific and technical information, by agency, fiscal years 1964, 1965, and 1966*—Continued

[Thousands of dollars]

Agency and subdivision	Actual 1964	Estimates	
		1965	1966
DEPARTMENT OF THE INTERIOR, TOTAL	8,232	8,673	10,338
Bureau of Commercial Fisheries	947	1,041	1,107
Bureau of Mines	885	925	960
Bureau of Outdoor Recreation	6	10	10
Bureau of Reclamation	260	299	347
Bureau of Sport Fisheries and Wildlife	444	462	492
Department Library	235	232	582
Geological Survey	5,321	5,523	6,530
National Park Service	35	44	57
Office of Coal Research	12	13	25
Office of Saline Water	87	110	184
Office of Water Resources Research	....	14	44
DEPARTMENT OF LABOR, TOTAL	109	154	157
Bureau of Employment Security	26	47	50
Bureau of Labor Standards	13	13	13
Office of Manpower, Automation, and Training	58	80	80
Women's Bureau	12	14	14
DEPARTMENT OF STATE, TOTAL	371	229	246
Agency for International Development	311	173	197
Departmental funds	60	56	49
DEPARTMENT OF THE TREASURY, TOTAL	31	36	45
United States Coast Guard	31	36	45
Other Agencies			
ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS	36	36	36
ATOMIC ENERGY COMMISSION	4,597	4,741	5,474
FEDERAL AVIATION AGENCY	452	612	528
FEDERAL COMMUNICATIONS COMMISSION	13	13	13
FEDERAL HOME LOAN BANK BOARD	8	10	11
LIBRARY OF CONGRESS	9,287	10,068	12,485
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	19,616	22,400	26,870
NATIONAL SCIENCE FOUNDATION	12,387	13,370	14,100
OFFICE OF EMERGENCY PLANNING	....	3	3
SMALL BUSINESS ADMINISTRATION	21	25	25
SMITHSONIAN INSTITUTION	850	1,049	1,576
TENNESSEE VALLEY AUTHORITY	25	25	25
UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY	900	980	1,120
VETERANS ADMINISTRATION	502	407	539

TABLE D-3. *Federal obligations for scientific and technical information, by agency and activity, fiscal year 1964*

[Thousands of dollars]

Agency and subdivision	Total, all activities	Publication and distribution: Total	Publication and distribution: Publication and distribution	Publication and distribution: Support of publications	Documentation, reference, and information services: Total	Documentation, reference, and information services: Bibliographic and reference services	Documentation, reference, and information services: Specialized information centers	Documentation, reference, and information services: Translations	Symposia and audio/visual media: Total	Symposia and audio/visual media: Symposia and technical meetings	Symposia and audio/visual media: Audio/visual media and other forms of oral communication	R&D in information sciences, documentation and information systems, techniques and devices	Management and administration—information programs and services
TOTAL, ALL AGENCIES	203,194	59,858	57,984	1,874	90,803	76,313	10,545	3,945	22,665	13,880	8,785	12,628	17,240
Departments													
DEPARTMENT OF AGRICULTURE, TOTAL	5,230	1,759	1,591	168	1,755	1,744		11	1,354	1,294	60	67	295
Agricultural Research Service	1,460	555	400	155	225	217		8	656	656			24
Cooperative State Research Service	84	21	21						50	50		13	
Economic Research Service	245	213	213		2	2			30	30			
Farmer Cooperative Service	105	92	92						13	7	6		
Forest Service	1,581	726	713	13	161	158		3	503	449	54	35	156
National Agricultural Library	1,652	145	145		1,367	1,367			6	6		19	115
Soil Conservation Service	94								94	94			
Statistical Reporting Service	9	7	7						2	2			
DEPARTMENT OF COMMERCE, TOTAL	32,612	18,409	18,406	3	9,013	7,275	1,604	134	617	563	54	1,048	3,525
Bureau of the Census	211	58	58		26	16	10		41	41		86	
Bureau of Public Roads	418	120	120		143	143			15	15		140	
Coast and Geodetic Survey	95	44	44		4	2		2	28	13	15	2	17
Maritime Administration	23								23	4	19		
National Bureau of Standards	4,637	1,740	1,740		2,269	633	1,564	72	461	441	20	167	
Office of Business Economics	90	90	90										
Patent Office	26,750	16,278	16,278		6,319	6,259		60	22	22		623	3,508
Weather Bureau	388	79	76	3	252	222	30		27	27		30	
DEPARTMENT OF DEFENSE, TOTAL	83,652	18,594	18,568	26	41,006	36,703	3,977	326	10,834	4,030	6,804	3,854	9,364
DEPARTMENT OF THE ARMY	49,723	10,558	10,558		24,242	24,106		136	5,572		5,572	1,571	7,780
DEPARTMENT OF THE NAVY	14,361	5,299	5,299		7,033	5,482	1,551		1,551	1,551		478	
DEPARTMENT OF THE AIR FORCE	12,357	2,580	2,554	26	4,150	1,653	2,307	190	3,258	2,426	832	1,455	914
DEFENSE AGENCIES	7,211	157	157		5,581	5,462	119		453	53	400	350	670
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	24,263	3,829	3,030	799	10,349	7,081	2,721	547	5,514	4,302	1,212	2,498	2,073
Food and Drug Administration	367	90	90		30	30			100	100		114	33
Office of Education	562	93	93		79	79			301	301		66	23
Public Health Service	22,917	3,418	2,648	770	10,148	6,938	2,665	545	5,016	3,804	1,212	2,318	2,017
National Institutes of Health	(13,691)	(2,021)	(1,492)	(529)	(4,974)	(2,816)	(1,905)	(253)	(3,764)	(3,263)	(501)	(1,894)	(1,038)
National Library of Medicine	(4,595)	(283)	(74)	(209)	(3,787)	(3,527)		(260)					(525)
Saint Elizabeths Hospital	3	2	2						1	1			
Social Security Administration	148	140	140						8	8			

Vocational Rehabilitation Administration	160	29		29	72	14	56	2	59	59			
Welfare Administration	106	57	57		20	20			29	29			
DEPARTMENT OF THE INTERIOR, TOTAL	8, 232	5, 445	5, 440	5	1, 665	1, 384	190	91	381	377	4	530	211
Bureau of Commercial Fisheries	947	529	529		374	191	141	42	18	18		25	1
Bureau of Mines	885	596	596		235	235			45	45			9
Bureau of Outdoor Recreation	6	5		5	1	1							
Bureau of Reclamation	260	32	32		156	98	49	9	19	15	4	4	49
Bureau of Sport Fisheries and Wildlife	444	234	234		43	43			162	162		5	
Department Library	235				225	220		5				10	
Geological Survey	5, 321	3, 984	3, 984		573	538		35	126	126		486	152
National Park Service	35	31	31		1	1			3	3			
Office of Coal Research	12	11	11						1	1			
Office of Saline Water	87	23	23		57	57			7	7			
DEPARTMENT OF LABOR, TOTAL	109	63	63		29	29			16	16			1
Bureau of Employment Security	26	9	9						16	16			1
Bureau of Labor Standards	13	13	13										
Office of Manpower, Automation, and Training	58	29	29		29	29							
Women's Bureau	12	12	12										
DEPARTMENT OF STATE, TOTAL	371	40	40		69	69			262	262			
Agency for International Development	311	40	40		25	25			246	246			
Departmental funds	60				44	44			16	16			
DEPARTMENT OF THE TREASURY, TOTAL	31	11	11		20		20						
United States Coast Guard	31	11	11		20		20						
Other Agencies													
ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS	36	24	24		10	10			2	2			
ATOMIC ENERGY COMMISSION	4, 597	2, 060	2, 060		1, 891	1, 830		61	185	185		267	194
FEDERAL AVIATION AGENCY	452	134	134		208	208			59	54	5		51
FEDERAL COMMUNICATIONS COMMISSION	13	3	3		5	5			5	5			
FEDERAL HOME LOAN BANK BOARD	8				8	8							
LIBRARY OF CONGRESS	9, 287				9, 212	9, 212			3	3		72	
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	19, 616	7, 828	7, 798	30	9, 548	8, 904	401	243	1, 623	1, 081	542	317	300
NATIONAL SCIENCE FOUNDATION	12, 387	1, 032	253	779	5, 512	1, 348	1, 632	2, 532	1, 338	1, 308	30	3, 768	737
SMALL BUSINESS ADMINISTRATION	21	21	21										
SMITHSONIAN INSTITUTION	850	349	335	14	347	347			74	74			80
TENNESSEE VALLEY AUTHORITY	25				25	25							
UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY	900	200	150	50	50	50			100	50	50	160	390
VETERANS ADMINISTRATION	502	57	57		81	81			298	274	24	47	19

TABLE D-4. *Federal obligations for scientific and technical information, by agency and activity, fiscal year 1965 (estimated)*

[Thousands of dollars]

Agency and subdivision	Total, all activities	Publication and distribution: Total	Publication and distribution: Publication and distribution	Publication and distribution: Support of publications	Documentation, reference, and information services: Total	Documentation, reference, and information services: Bibliographic and reference services	Documentation, reference, and information services: Specialized information centers	Documentation, reference, and information services: Translations	Symposia and audio/visual media: Total	Symposia and audio/visual media: Symposia and technical meetings	Symposia and audio/visual media: Audio/visual media and other forms of oral communication	R&D in information sciences, documentation and information systems, techniques and devices	Management and administration—information programs and services
TOTAL, ALL AGENCIES	222, 848	66, 806	64, 090	2, 716	101, 226	85, 309	11, 866	4, 051	23, 726	15, 001	8, 725	11, 927	19, 163
Departments													
DEPARTMENT OF AGRICULTURE, TOTAL	5, 777	2, 006	1, 812	194	1, 712	1, 698		14	1, 544	1, 455	89	175	340
Agricultural Research Service	1, 686	647	463	184	262	252		10	751	751			26
Cooperative State Research Service	64	7	7						55	55		2	
Economic Research Service	253	195	195		1	1			57	32	25		
Farmer Cooperative Service	112	98	98						14	7	7		
Forest Service	1, 847	832	822	10	230	226		4	565	508	57	37	183
National Agricultural Library	1, 711	219	219		1, 219	1, 219			6	6		136	131
Soil Conservation Service	94								94	94			
Statistical Reporting Service	10	8	8						2	2			
DEPARTMENT OF COMMERCE, TOTAL	37, 098	20, 725	20, 722	3	10, 603	8, 744	1, 694	165	645	595	50	1, 222	3, 903
Bureau of the Census	232	66	66		29	18	11		41	41		96	
Bureau of Public Roads	467	121	121		143	143			20	20		183	
Coast and Geodetic Survey	205	125	125		20	10		10	40	15	25	2	18
Maritime Administration	3								3		3		
National Bureau of Standards	5, 387	2, 224	2, 224		2, 462	736	1, 646	80	491	469	22	210	
Office of Business Economics	95	95	95										
Patent Office	30, 180	17, 965	17, 965		7, 690	7, 625		65	22	22		668	3, 835
Weather Bureau	529	129	126	3	259	212	37	10	28	28		63	50
DEPARTMENT OF DEFENSE, TOTAL	92, 797	20, 264	19, 698	566	46, 744	42, 541	3, 890	313	11, 457	4, 525	6, 932	3, 880	10, 452
DEPARTMENT OF THE ARMY	52, 209	11, 086	11, 086		25, 454	25, 311		143	5, 850		5, 850	1, 650	8, 169
DEPARTMENT OF THE NAVY	15, 398	5, 721	5, 701	20	7, 508	6, 221	1, 287		1, 651	1, 651		518	
DEPARTMENT OF THE AIR FORCE	13, 927	3, 287	2, 741	546	4, 554	1, 949	2, 435	170	3, 551	2, 809	742	1, 447	1, 088
DEFENSE AGENCIES	11, 263	170	170		9, 228	9, 060	168		405	65	340	265	1, 195
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	24, 345	4, 019	3, 119	900	10, 356	6, 825	2, 947	584	5, 517	4, 509	1, 008	2, 119	2, 334
Food and Drug Administration	445	105	105		130	130			115	115		65	30
Office of Education	700	107	107		80	80			300	300		181	32
Public Health Service	22, 709	3, 567	2, 697	870	10, 038	6, 582	2, 874	582	4, 959	3, 951	1, 008	1, 873	2, 272
National Institutes of Health	(14, 224)	(2, 270)	(1, 666)	(604)	(5, 077)	(2, 665)	(2, 143)	(269)	(3, 876)	(3, 363)	(513)	(1, 769)	(1, 232)
National Library of Medicine	(4, 554)	(320)	(84)	(236)	(3, 557)	(3, 274)		(283)				(45)	(632)
Saint Elizabeths Hospital	5	4	4						1	1			
Social Security Administration	181	164	164						17	17			
Vocational Rehabilitation Administration	212	30		30	88	13	73	2	94	94			

Welfare Administration	93	42	42		20	20			31	31			
Department of the Interior, total	8, 673	5, 636	5, 634	2	1, 775	1, 463	230	82	440	437	3	595	227
Bureau of Commercial Fisheries	1, 041	608	608		413	216	167	30	19	19			1
Bureau of Mines	925	623	623		242	242			50	50			10
Bureau of Outdoor Recreation	10	2		2	6	6						2	
Bureau of Reclamation	299	30	30		191	120	61	10	15	12	3	5	58
Bureau of Sport Fisheries and Wildlife	462	239	239		45	45			172	172		6	
Department Library	232				218	214		4				14	
Geological Survey	5, 523	4, 050	4, 050		600	562		38	147	147		568	158
National Park Service	44	40	40		1	1			3	3			
Office of Coal Research	13	10	10						3	3			
Office of Saline Water	110	23	23		57	57			30	30			
Office of Water Resources Research	14	11	11		2		2		1	1			
Department of Labor, total	154	78	78		40	40			34	34			2
Bureau of Employment Security	47	11	11						34	34			2
Bureau of Labor Standards	13	13	13										
Office of Manpower, Automation, and Training	80	40	40		40	40							
Women's Bureau	14	14	14										
Department of State, total	229	11	11		80	80			110	110			28
Agency for International Development	173	11	11		34	34			100	100			28
Departmental funds	56				46	46			10	10			
Department of the Treasury, total	36	11	11		25		25						
United States Coast Guard	36	11	11		25		25						
Other Agencies													
Advisory Commission on Intergovernmental Relations	36	24	24		10	10			2	2			
Atomic Energy Commission	4, 741	2, 209	2, 209		1, 756	1, 676		80	259	259		300	217
Federal Aviation Agency	612	171	171		317	317			70	65	5		54
Federal Communications Commission	13	3	3		5	5			5	5			
Federal Home Loan Bank Board	10				10	10							
Library of Congress	10, 068				9, 927	9, 927			5	5		136	
National Aeronautics and Space Administration	22, 400	9, 749	9, 718	31	10, 075	9, 332	480	263	1, 876	1, 318	558	350	350
National Science Foundation	13, 370	1, 234	284	950	7, 162	2, 012	2, 600	2, 550	1, 255	1, 225	30	3, 000	719
Office of Emergency Planning	3				3	3							
Small Business Administration	25	25	25										
Smithsonian Institution	1, 049	371	351	20	509	509			84	84			85
Tennessee Valley Authority	25				25	25							
United States Arms Control and Disarmament Agency	980	200	150	50	50	50			150	100	50	150	430
Veterans Administration	407	70	70		42	42			273	273			22

TABLE D-5. *Federal obligations for scientific and technical information, by agency and activity, fiscal year 1966 (estimated)*

[Thousands of dollars]

Agency and subdivision	Total, all activities	Publication and distribution: Total	Publication and distribution: Publication and distribution	Publication and distribution: Support of publications	Documentation, reference, and information services: Total	Documentation, reference, and information services: Bibliographic and reference services	Documentation, reference, and information services: Specialized information centers	Documentation, reference, and information services: Translations	Symposia and audio/visual media: Total	Symposia and audio/visual media: Symposia and technical meetings	Symposia and audio/visual media: Audio/visual media and other forms of oral communication	R&D in information sciences, documentation and information systems, techniques and devices	Management and administration—information programs and services
TOTAL, ALL AGENCIES	258, 673	71, 518	69, 071	2, 447	120, 169	101, 340	15, 169	3, 660	25, 478	16, 014	9, 464	18, 326	23, 182
Departments													
DEPARTMENT OF AGRICULTURE, TOTAL	13, 156	2, 269	2, 045	224	8, 757	8, 742	....	15	1, 601	1, 534	67	176	353
Agricultural Research Service	1, 828	749	535	214	272	262	....	10	781	781	....	....	26
Cooperative State Research Service	62	5	5	....	....	....	....	....	55	55	....	2	....
Economic Research Service	229	197	197	....	1	1	....	....	31	31	....	....	....
Farmer Cooperative Service	122	107	107	....	....	....	....	....	15	8	7	....	....
Forest Service	1, 939	859	849	10	242	237	....	5	615	555	60	31	192
National Agricultural Library	8, 868	343	343	....	8, 242	8, 242	....	....	7	7	....	142	134
Soil Conservation Service	94	....	....	....	....	....	....	....	94	94	....	....	....
Statistical Reporting Service	14	9	9	....	....	....	....	....	3	3	....	1	1
DEPARTMENT OF COMMERCE, TOTAL	41, 090	22, 156	22, 153	3	12, 819	10, 459	2, 178	182	753	700	53	1, 358	4, 004
Bureau of the Census	206	66	66	....	29	18	11	....	41	41	....	70	....
Bureau of Public Roads	500	127	127	....	143	143	....	....	20	20	....	210	....
Coast and Geodetic Survey	185	91	91	....	27	17	....	10	47	17	30	2	18
Maritime Administration	5	....	....	....	....	....	....	....	5	5	....	....	....
National Bureau of Standards	7, 130	3, 234	3, 234	....	3, 020	801	2, 129	90	587	564	23	289	....
Office of Business Economics	100	100	100	....	....	....	....	....	....	....	....	....	....
Patent Office	32, 360	18, 400	18, 400	....	9, 320	9, 250	....	70	22	22	....	684	3, 934
Weather Bureau	604	138	135	3	280	230	38	12	31	31	....	103	52
DEPARTMENT OF DEFENSE, TOTAL	99, 628	19, 803	19, 703	100	47, 777	41, 865	5, 557	355	11, 614	4, 258	7, 356	6, 541	13, 893
DEPARTMENT OF THE ARMY	54, 819	11, 640	11, 640	....	26, 726	26, 576	....	150	6, 143	....	6, 143	1, 733	8, 577
DEPARTMENT OF THE NAVY	13, 319	5, 057	5, 026	31	3, 736	3, 197	487	52	1, 437	1, 327	110	514	2, 575
DEPARTMENT OF THE AIR FORCE	20, 253	2, 923	2, 854	69	7, 927	3, 004	4, 770	153	3, 616	2, 856	760	4, 244	1, 543
DEFENSE AGENCIES	11, 237	183	183	....	9, 388	9, 088	300	....	418	75	343	50	1, 198
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	31, 208	4, 633	3, 614	1, 019	14, 114	9, 702	3, 676	736	6, 316	5, 146	1, 170	3, 512	2, 633
Food and Drug Administration	2, 340	100	100	....	2, 050	2, 050	....	....	75	75	....	45	70
Office of Education	739	114	114	....	80	80	....	....	300	300	....	210	35
Public Health Service	27, 611	4, 157	3, 170	987	11, 874	7, 539	3, 601	734	5, 795	4, 625	1, 170	3, 257	2, 528
National Institutes of Health	(17, 587)	(2, 584)	(1, 921)	(663)	(5, 932)	(2, 897)	(2, 741)	(294)	(4, 574)	(3, 996)	(578)	(3, 133)	(1, 364)
National Library of Medicine	(5, 484)	(411)	(120)	(291)	(4, 351)	(3, 945)	....	(406)	....	....	....	(50)	(672)
Saint Elizabeths Hospital	6	4	4	....	....	....	....	....	2	2	....	....	....
Social Security Administration	200	183	183	....	....	....	....	....	17	17	....	....	....
Vocational Rehabilitation Administration	217	32	....	32	90	13	75	2	95	95	....	....	....

Welfare Administration	95	43	43		20	20			32	32			
DEPARTMENT OF THE INTERIOR, TOTAL	10, 338	6, 180	6, 176	4	2, 727	2, 091	511	125	513	507	6	676	242
Bureau of Commercial Fisheries	1, 107	627	625	2	460	220	190	50	19	19			1
Bureau of Mines	960	650	650		250	250			50	50			10
Bureau of Outdoor Recreation	10	2		2	6	6						2	
Bureau of Reclamation	347	52	52		220	140	70	10	21	15	6	8	46
Bureau of Sport Fisheries and Wildlife	492	241	241		70	70			150	150		31	
Department Library	582				572	472	80	20				10	
Geological Survey	6, 530	4, 486	4, 486		1, 075	865	165	45	159	159		625	185
National Park Service	57	53	53		1	1			3	3			
Office of Coal Research	25	16	16		3	3			6	6			
Office of Saline Water	184	25	25		64	64			95	95			
Office of Water Resources Research	44	28	28		6		6		10	10			
DEPARTMENT OF LABOR, TOTAL	157	81	81		40	40			34	34			2
Bureau of Employment Security	50	14	14						34	34			2
Bureau of Labor Standards	13	13	13										
Office of Manpower, Automation, and Training	80	40	40		40	40							
Women's Bureau	14	14	14										
DEPARTMENT OF STATE, TOTAL	246				215	215			3	3			28
Agency for International Development	197				169	169							28
Departmental funds	49				46	46			3	3			
DEPARTMENT OF THE TREASURY, TOTAL	45	13	13		32		32						
United States Coast Guard	45	13	13		32		32						
Other Agencies													
ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS	36	24	24		10	10			2	2			
ATOMIC ENERGY COMMISSION	5, 474	2, 384	2, 384		1, 827	1, 747		80	298	298		743	222
FEDERAL AVIATION AGENCY	528	192	192		217	217			64	59	5		55
FEDERAL COMMUNICATIONS COMMISSION	13	3	3		5	5			5	5			
FEDERAL HOME LOAN BANK BOARD	11				11	11							
LIBRARY OF CONGRESS	12, 485				12, 004	12, 004			7	7		474	
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	26, 870	11, 703	11, 666	37	12, 100	11, 235	565	300	2, 246	1, 574	672	421	400
NATIONAL SCIENCE FOUNDATION	14, 100	1, 324	334	990	6, 529	2, 012	2, 650	1, 867	1, 310	1, 280	30	4, 200	737
OFFICE OF EMERGENCY PLANNING	3				3	3							
SMALL BUSINESS ADMINISTRATION	25	25	25										
SMITHSONIAN INSTITUTION	1, 576	452	432	20	794	794			185	185		25	120
TENNESSEE VALLEY AUTHORITY	25				25	25							
UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY	1, 120	200	150	50	50	50			200	125	75	200	470
VETERANS ADMINISTRATION	539	76	76		113	113			327	297	30		23

TABLE D-6. *Federal intramural and extramural obligations for scientific and technical information, by agency, fiscal years 1964, 1965, and 1966*

[Thousands of dollars]

Agency and subdivision	Intramural			Extramural		
	Actual 1964	Estimates 1965	Estimates 1966	Actual 1964	Estimates 1965	Estimates 1966
TOTAL, ALL AGENCIES	142,745	158,995	181,804	60,449	63,853	76,869
Departments						
DEPARTMENT OF AGRICULTURE, TOTAL	5,210	5,753	13,133	20	24	23
Agricultural Research Service	1,458	1,683	1,825	2	3	3
Cooperative State Research Service	84	64	62	....	....	....
Economic Research Service	245	253	229	....	....	....
Farmer Cooperative Service	105	112	122	....	....	....
Forest Service	1,563	1,826	1,919	18	21	20
National Agricultural Library	1,652	1,711	8,868	....	....	....
Soil Conservation Service	94	94	94	....	....	....
Statistical Reporting Service	9	10	14	....	....	....
DEPARTMENT OF COMMERCE, TOTAL	31,956	36,339	39,383	656	759	1,707
Bureau of the Census	197	218	192	14	14	14
Bureau of Public Roads	229	278	280	189	189	220
Coast and Geodetic Survey	80	180	155	15	25	30
Maritime Administration	2	....	3	21	3	2
National Bureau of Standards	4,308	4,964	5,827	329	423	1,303
Office of Business Economics	90	95	100	....	....	....
Patent Office	26,715	30,145	32,325	35	35	35
Weather Bureau	335	459	501	53	70	103
DEPARTMENT OF DEFENSE, TOTAL	59,429	67,266	69,087	24,223	25,531	30,541
DEPARTMENT OF THE ARMY	36,126	37,932	39,828	13,597	14,277	14,991
DEPARTMENT OF THE NAVY	10,998	11,888	6,332	3,363	3,510	6,987
DEPARTMENT OF THE AIR FORCE	5,755	6,871	12,330	6,602	7,056	7,923
DEFENSE AGENCIES	6,550	10,575	10,597	661	688	640
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	13,596	13,790	17,890	10,667	10,555	13,318
Food and Drug Administration	308	345	1,450	59	100	890
Office of Education	129	262	301	433	438	438
Public Health Service	12,898	12,900	15,833	10,019	9,809	11,778
National Institutes of Health	(4,469)	(5,306)	(6,597)	(9,222)	(8,918)	(10,990)
National Library of Medicine	(3,917)	(3,719)	(4,787)	(678)	(835)	(697)
Saint Elizabeths Hospital	3	5	6	....	....	....
Social Security Administration	148	181	200	....	....	....
Vocational Rehabilitation Administration	4	4	5	156	208	212
Welfare Administration	106	93	95	....	....	....

TABLE D-6. *Federal intramural and extramural obligations for scientific and technical information, by agency, fiscal years 1964, 1965, and 1966*—Continued

[Thousands of dollars]

Agency and subdivision	Intramural			Extramural		
	Actual 1964	Estimates 1965	Estimates 1966	Actual 1964	Estimates 1965	Estimates 1966
DEPARTMENT OF THE INTERIOR, TOTAL	8,061	8,531	10,181	171	142	157
Bureau of Commerical Fisheries	886	1,022	1,086	61	19	21
Bureau of Mines	885	925	960	....	....	....
Bureau of Reclamation	251	289	335	9	10	12
Bureau of Sport Fisheries and Wildlife	408	426	463	36	36	29
Bureau of Outdoor Recreation	6	5	5	....	5	5
Department Library	235	232	582	....	....	....
Geological Survey	5,321	5,523	6,530	....	....	....
National Park Service	35	44	57	....	....	....
Office of Coal Research	7	7	12	5	6	13
Office of Saline Water	27	50	115	60	60	69
Office of Water Resources Research	....	8	36	....	6	8
DEPARTMENT OF LABOR, TOTAL	109	154	157	....	....	....
Bureau of Employment Security	26	47	50	....	....	....
Bureau of Labor Standards	13	13	13	....	....	....
Office of Manpower, Automation, and Training	58	80	80	....	....	....
Women's Bureau	12	14	14	....	....	....
DEPARTMENT OF STATE, TOTAL	72	111	111	299	118	135
Agency for International Development	25	62	62	286	111	135
Departmental funds	47	49	49	13	7	....
DEPARTMENT OF THE TREASURY, TOTAL	31	36	45	....	....	....
United States Coast Guard	31	36	45	....	....	....
Other Agencies						
ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS	36	36	36	....	....	....
ATOMIC ENERGY COMMISSION	2,531	2,816	2,954	2,066	1,925	2,520
FEDERAL AVIATION AGENCY	425	495	523	27	117	5
FEDERAL COMMUNICATIONS COMMISSION	13	13	13	....	....	....
FEDERAL HOME LOAN BANK BOARD	8	10	11	....	....	....
LIBRARY OF CONGRESS	9,287	10,035	12,252	....	33	233
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	7,114	7,550	9,050	12,502	14,850	17,820
NATIONAL SCIENCE FOUNDATION	2,700	3,608	3,723	9,687	9,762	10,377
OFFICE OF EMERGENCY PLANNING	....	3	3	....	....	....
SMALL BUSINESS ADMINISTRATION	21	25	25	....	....	....
SMITHSONIAN INSTITUTION	850	1,049	1,576	....	....	....
TENNESSEE VALLEY AUTHORITY	25	25	25	....	....	....
UNITED STATES ARMS CONTROL AND DISARMAMSNT AGECNY	890	980	1,120	10	....	....
VETERANS ADMINSTRATION	381	370	506	121	37	33

TABLE D-7. *Federal intramural and extramural obligations for scientific and technical information, by agency and activity, fiscal year 1964*

[Thousands of dollars]

Agency and subdivision	Total	Intramural					
		Total intramural	Publication and distribution	Documentation, reference, and information services	Symposia and audio/visual media	R&D in information sciences, documentation and information systems, techniques and devices	Management and administration—information programs and services
TOTAL, ALL AGENCIES	203,194	142,745	44,347	65,465	14,052	3,839	15,042
Departments							
DEPARTMENT OF AGRICULTURE, TOTAL	5,230	5,210	1,759	1,750	1,354	52	295
Agricultural Research Service	1,460	1,458	555	223	656		24
Cooperative State Research Service	84	84	21		50	13	
Economic Research Service	245	245	213	2	30		
Farmer Cooperative Service	105	105	92		13		
Forest Service	1,581	1,563	726	158	503	20	156
National Agricultural Library	1,652	1,652	145	1,367	6	19	115
Soil Conservation Service	94	94			94		
Statistical Reporting Service	9	9	7		2		
DEPARTMENT OF COMMERCE, TOTAL	32,612	31,956	18,060	8,926	565	880	3,525
Bureau of the Census	211	197	58	26	27	86	
Bureau of Public Roads	418	229	56	143	15	15	
Coast and Geodetic Survey	95	80	44	4	13	2	17
Maritime Administration	23	2			2		
National Bureau of Standards	4,637	4,308	1,458	2,232	461	157	
Office of Business Economics	90	90	90				
Patent Office	26,750	26,715	16,278	6,319	20	590	3,508
Weather Bureau	388	335	76	202	27	30	
DEPARTMENT OF DEFENSE, TOTAL	83,652	59,429	11,413	31,595	7,891	1,202	7,328
DEPARTMENT OF ARMY	49,723	36,126	5,373	19,077	5,028	779	5,869
DEPARTMENT OF THE NAVY	14,361	10,998	4,103	5,351	1,364	180	
DEPARTMENT OF THE AIR FORCE	12,357	5,755	1,865	1,784	1,074	243	789
DEFENSE AGENCIES	7,211	6,550	72	5,383	425		670
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	24,263	13,596	2,356	6,268	2,306	606	2,060
Food and Drug Administration	367	308	90	30	100	55	33
Office of Education	562	129	49	70			10
Public Health Service	22,917	12,898	2,018	6,148	2,164	551	2,017
National Institutes of Health	(13,691)	(4,469)	(840)	(1,491)	(973)	(127)	(1,038)
National Library of Medicine	(4,595)	(3,917)	(74)	(3,318)			(525)
Saint Elizabeths Hospital	3	3	2		1		
Social Security Administration	148	148	140		8		
Vocational Rehabilitation Administration	160	4			4		
Welfare Administration	106	106	57	20	29		
DEPARTMENT OF THE INTERIOR, TOTAL	8,232	8,061	5,409	1,603	335	505	209
Bureau of Commercial Fisheries	947	886	529	356			1
Bureau of Mines	885	885	596	235	45		9
Bureau of Outdoor Recreation	6	6	5	1			
Bureau of Reclamation	260	251	32	150	18	4	47
Bureau of Sport Fisheries and Wildlife	444	408	220	43	140	5	
Department Library	235	235		225		10	
Geological Survey	5,321	5,321	3,984	573	126	486	152
National Park Service	35	35	31	1	3		
Office of Coal Research	12	7	6		1		
Office of Saline Water	87	27	6	19	2		
DEPARTMENT OF LABOR, TOTAL	109	109	63	29	16		1
Bureau of Employment Security	26	26	9		16		1
Bureau of Labor Standards	13	13	13				
Office of Manpower, Automation, and Training	58	58	29	29			
Women's Bureau	12	12	12				
DEPARTMENT OF STATE, TOTAL	371	72		69	3		
Agency for International Development	311	25		25			
Departmental funds	60	47		44	3		
DEPARTMENT OF THE TREASURY, TOTAL	31	31	11	20			
United States Coast Guard	31	31	11	20			
Other Agencies							
ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS	36	36	24	10	2		
ATOMIC ENERGY COMMISSION	4,597	2,531	1,415	721	53	148	194
FEDERAL AVIATION AGENCY	452	425	134	181	59		51
FEDERAL COMMUNICATIONS COMMISSION	13	13	3	5	5		
FEDERAL HOME LOAN BANK BOARD	8	8		8			
LIBRARY OF CONGRESS	9,287	9,287		9,212	3	72	
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	19,616	7,114	2,973	2,932	1,022	34	153
NATIONAL SCIENCE FOUNDATION	12,387	2,700	107	1,698		158	737
SMALL BUSINESS ADMINISTRATION	21	21	21				
SMITHSONIAN INSTITUTION	850	850	349	347	74		80
TENNESSEE VALLEY AUTHORITY	25	25		25			
UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY	900	890	200	50	100	150	390
VETERANS ADMINISTRATION	502	381	50	16	264	32	19

Table D-7. *Federal intramural and extramural obligations for scientific and technical information, by agency and activity, fiscal year 1964*—Continued

[Thousands of dollars]

Agency and subdivision	Extramural: Total extramural	Publication and distribution	Documentation, reference, and information services	Symposia and audio/visual media	R&D in information sciences, documentation and information systems, techniques and devices	Management and administration—information programs and services
TOTAL, ALL AGENCIES	60,449	15,511	25,338	8,613	8,789	2,198
Departments						
Department of Agriculture, total	20	.....	5	.....	15	.....
Agricultural Research Service	2	.....	2	.....	.....	.....
Cooperative State Research Service	.....	.....	.....	.....	.....	.....
Economic Research Service	.....	.....	.....	.....	.....	.....
Farmer Cooperative Service	.....	.....	.....	.....	.....	.....
Forest Service	18	.....	3	.....	15	.....
National Agricultural Library	.....	.....	.....	.....	.....	.....
Soil Conservation Service	.....	.....	.....	.....	.....	.....
Statistical Reporting Service	.....	.....	.....	.....	.....	.....
Department of Commerce, total	656	349	87	52	168	.....
Bureau of the Census	14	.....	.....	14	.....	.....
Bureau of Public Roads	189	64	.....	.....	125	.....
Coast and Geodetic Survey	15	.....	.....	15	.....	.....
Maritime Administration	21	.....	.....	21	.....	.....
National Bureau of Standards	329	282	37	.....	10	.....
Office of Business Economics	.....	.....	.....	.....	.....	.....
Patent Office	35	.....	.....	2	33	.....
Weather Bureau	53	3	50	.....	.....	.....
Department of Defense, Total	24,223	7,181	9,411	2,943	2,652	2,036
Department of the Army	13,597	5,185	5,165	544	792	1,911
Department of the Navy	3,363	1,196	1,682	187	298	.....
Department of the Air Force	6,602	715	2,366	2,184	1,212	125
Defense agencies	661	85	198	28	350	.....
Department of Health, Education, and Welfare, total	10,667	1,473	4,081	3,208	1,892	13
Food and Drug Administration	59	.....	.....	.....	59	.....
Office of Education	433	44	9	301	66	13
Public Health Service	10,019	1,400	4,000	2,852	1,767	.....
National Institutes of Health	(9,222)	(1,181)	(3,483)	(2,791)	(1,767)	.....
National Library of Medicine	(678)	(209)	(469)	.....	.....	.....
Saint Elizabeths Hospital	.....	.....	.....	.....	.....	.....
Social Security Administration	.....	.....	.....	.....	.....	.....
Vocational Rehabilitation Administration	156	29	72	55	.....	.....
Welfare Administration	.....	.....	.....	.....	.....	.....
Department of the Interior, total	171	36	62	46	25	2
Bureau of Commercial Fisheries	61	.....	18	18	25	.....
Bureau of Mines	.....	.....	.....	.....	.....	.....
Bureau of Reclamation	9	.....	6	1	.....	2
Bureau of Sport Fisheries and Wildlife	36	14	.....	22	.....	.....
Bureau of Outdoor Recreation	.....	.....	.....	.....	.....	.....
Department Library	.....	.....	.....	.....	.....	.....
Geological Survey	.....	.....	.....	.....	.....	.....
National Park Service	.....	.....	.....	.....	.....	.....
Office of Coal Research	5	5	.....	.....	.....	.....
Office of Saline Water	60	17	38	5	.....	.....
Department of Labor, total	.....	.....	.....	.....	.....	.....
Bureau of Employment Security	.....	.....	.....	.....	.....	.....
Bureau of Labor Standards	.....	.....	.....	.....	.....	.....
Office of Manpower, Automation, and Training	.....	.....	.....	.....	.....	.....
Women's Bureau	.....	.....	.....	.....	.....	.....
Department of State, total	299	40	.....	259	.....	.....
Agency for International Development	286	40	.....	246	.....	.....
Departmental funds	13	.....	.....	13	.....	.....
Department of the Treasury, total	.....	.....	.....	.....	.....	.....
United States Coast Guard	.....	.....	.....	.....	.....	.....
Other Agencies						
Advisory Commission on Intergovernmental Relations	.....	.....	.....	.....	.....	.....
Atomic Energy Commission	2,066	645	1,170	132	119	.....
Federal Aviation Agency	27	.....	27	.....	.....	.....
Federal Communications Commission	.....	.....	.....	.....	.....	.....
Federal Home Loan Bank Board	.....	.....	.....	.....	.....	.....
Library of Congress	.....	.....	.....	.....	.....	.....
National Aeronautics and Space Administration	12,502	4,855	6,616	601	283	147
National Science Foundation	9,687	925	3,814	1,338	3,610	.....
Small Business Administration	.....	.....	.....	.....	.....	.....
Smithsonian Institution	.....	.....	.....	.....	.....	.....
Tennessee Valley Authority	.....	.....	.....	.....	.....	.....
United States Arms Control and Disarmament Agency	10	.....	.....	.....	10	.....
Veterans Administration	121	7	65	34	15	.....

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Table D–8. *Federal intramural and extramural obligations for scientific and technical information, by agency and activity, fiscal year 1965 (estimated)*

[Thousands of dollars]

Agency and subdivision	Total	Intramural: Total intramural	Intramural: Publication and distribution	Intramural: Documentation, reference, and information services	Intramural: Symposia and audio/visual media	Intramural: R&D in information sciences, documentation and information systems, techniques and devices	Intramural: Management and administration—information programs and services
TOTAL, ALL AGENCIES	222,848	158,995	48,393	74,246	15,432	4,155	16,769
Departments							
DEPARTMENT OF AGRICULTURE, TOTAL	5,777	5,753	2,006	1,705	1,544	158	340
Agricultural Research Service	1,686	1,683	647	259	751		26
Cooperative States Research Service	64	64	7		55	2	
Economic Research Service	253	253	195	1	57		
Farmer Cooperative Service	112	112	98		14		
Forest Service	1,847	1,826	832	226	565	20	183
National Agricultural Library	1,711	1,711	219	1,219	6	136	131
Soil Conservation Service	94	94			94		
Statistical Reporting Service	10	10	8		2		
DEPARTMENT OF COMMERCE, TOTAL	37,098	36,339	20,282	10,526	601	1,027	3,903
Bureau of the Census	232	218	66	29	27	96	
Bureau of Public Roads	467	278	57	143	20	58	
Coast and Geodetic Survey	205	180	125	20	15	2	18
Maritime Administration	3						
National Bureau of Standards	5,387	4,964	1,848	2,435	491	190	
Office of Business Economics	95	95	95				
Patent Office	30,180	30,145	17,965	7,690	20	635	3,835
Weather Bureau	529	459	126	209	28	46	50
DEPARTMENT OF DEFENSE, TOTAL	92,797	67,266	12,184	36,846	8,588	1,403	8,245
DEPARTMENT OF THE ARMY	52,209	37,932	5,642	20,031	5,279	818	6,162
DEPARTMENT OF THE NAVY	15,398	11,888	4,355	5,804	1,464	265	
DEPARTMENT OF THE AIR FORCE	13,927	6,871	2,125	2,038	1,500	320	888
DEFENSE AGENCIES	11,263	10,575	62	8,973	345		1,195
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	24,345	13,790	2,401	6,246	2,390	432	2,321
Food and Drug Administration	445	345	105	30	115	65	30
Office of Education	700	262	57	70		116	19
Public Health Service	22,709	12,900	2,029	6,126	2,222	251	2,272
National Institutes of Health	(14,224)	(5,306)	(968)	(1,794)	(1,165)	(147)	(1,232)
National Library of Medicine	(4,554)	(3,719)	(84)	(2,958)		(45)	(632)
Saint Elizabeths Hospital	5	5	4		1		
Social Security Administration	181	181	164		17		
Vocational Rehabilitation Administration	212	4			4		
Welfare Administration	93	93	42	20	31		
DEPARTMENT OF THE INTERIOR, TOTAL	8,673	8,531	5,593	1,727	392	594	225
Bureau of Commercial Fisheries	1,041	1,022	608	413			1
Bureau of Mines	925	925	623	242	50		10
Bureau of Reclamation	299	289	30	184	14	5	56
Bureau of Sport Fisheries and Wildlife	462	426	225	45	150	6	
Bureau of Outdoor Recreation	10	5	1	3		1	
Department Library	232	232		218		14	
Geological Survey	5,523	5,523	4,050	600	147	568	158
National Park Service	44	44	40	1	3		
Office of Coal Research	13	7	5		2		
Office of Saline Water	110	50	6	19	25		
Office of Water Resources Research	14	8	5	2	1		
DEPARTMENT OF LABOR, TOTAL	154	154	78	40	34		2
Bureau of Employment Security	47	47	11		34		2
Bureau of Labor Standards	13	13	13				
Office of Manpower, Automation, and Training	80	80	40	40			
Women's Bureau	14	14	14				
DEPARTMENT OF STATE, TOTAL	229	111		80	3		28
Agency for International Development	173	62		34			28
Departmental funds	56	49		46	3		
DEPARTMENT OF THE TREASURY, TOTAL	36	36	11	25			
United States Coast Guard	36	36	11	25			
Other Agencies							
ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS	36	36	24	10	2		
ATOMIC ENERGY COMMISSION	4,741	2,816	1,559	829	59	152	217
FEDERAL AVIATION AGENCY	612	495	171	200	70		54
FEDERAL COMMUNICATION COMMISSION	13	13	3	5	5		
FEDERAL HOME LOAN BANK BOARD	10	10		10			
LIBRARY OF CONGRESS	10,068	10,035		9,927	5	103	
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	22,400	7,550	3,294	2,786	1,256	36	178
NATIONAL SCIENCE FOUNDATION	13,370	3,608	134	2,655		100	719
OFFICE OF EMERGENCY PLANNING	3	3		3			
SMALL BUSINESS ADMINISTRATION	25	25	25				
SMITHSONIAN INSTITUTION	1,049	1,049	371	509	84		85
TENNESSEE VALLEY AUTHORITY	25	25		25			
UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY	980	980	200	50	150	150	430
VETERANS ADMINISTRATION	407	370	57	42	249		22

TABLE D-8. *Federal intramural and extramural obligations for scientific and technical information, by agency and activity, fiscal year 1965 (estimated)*—Continued

[Thousands of dollars]

Agency and subdivision	Extramural: Total extramural	Publication and distribution	Documentation, reference, and information services	Symposia and audio/visual media	R&D in information sciences, documentation and information systems, techniques and devices	Management and administration—information programs and services
TOTAL, ALL AGENCIES	63,853	18,413	26,980	8,294	7,772	2,394
Departments						
DEPARTMENT OF AGRICULTURE, TOTAL	24		7		17	
Agricultural Research Service	3		3			
Cooperative State Research Service						
Economic Research Service						
Farmer Cooperative Service						
Forest Service	21		4		17	
National Agricultural Library						
Soil Conservation Service						
Statistical Reporting Service						
DEPARTMENT OF COMMERCE, TOTAL	759	443	77	44	195	
Bureau of the Census	14			14		
Bureau of Public Roads	189	64			125	
Coat and Geodetic Survey	25			25		
Maritime Administration	3			3		
National Bureau of Standards	423	376	27		20	
Office of Business Economics						
Patent Office	35			2	33	
Weather Bureau	70	3	50		17	
DEPARTMENT OF DEFENSE, TOTAL	25,531	8,080	9,898	2,869	2,477	2,207
DEPARTMENT OF THE ARMY	14,277	5,444	5,423	571	832	2,007
DEPARTMENT OF THE NAVY	3,510	1,366	1,704	187	253	
DEPARTMENT OF THE AIR FORCE	7,056	1,162	2,516	2,051	1,127	200
DEFENSE AGENCIES	688	108	255	60	265	
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	10,555	1,618	4,110	3,127	1,687	13
Food and Drug Administration	100		100			
Office of Education	438	50	10	300	65	13
Public Health Service	9,809	1,538	3,912	2,737	1,622	
National Institutes of Health	(8,918)	(1,302)	(3,283)	(2,711)	(1,622)	
National Library of Medicine	(835)	(236)	(599)			
Saint Elizabeths Hospital						
Social Security Administration						
Vocational Rehabilitation Administration	208	30	88	90		
Welfare Administration						
DEPARTMENT OF THE INTERIOR, TOTAL	142	43	48	48	1	2
Bureau of Commercial Fisheries	19			19		
Bureau of Mines						
Bureau of Reclamation	10		7	1		2
Bureau of Sport Fisheries and Wildlife	36	14		22		
Bureau of Outdoor Recreation	5	1	3		1	
Department Library						
Geological Survey						
National Park Service						
Office of Coal Research	6	5		1		
Office of Saline Water	60	17	38	5		
Office of Water Resources Research	6	6				
DEPARTMENT OF LABOR, TOTAL						
Bureau of Employment Security						
Bureau of Labor Standards						
Office of Manpower, Automation, and Training						
Women's Bureau						
DEPARTMENT OF STATE, TOTAL	118	11		107		
Agency for International Development	111	11		100		
Departmental funds	7			7		
DEPARTMENT OF THE TREASURY, TOTAL						
United States Coast Guard						
Other Agencies						
ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS						
ATOMIC ENERGY COMMISSION	1,925	650	927	200	148	
FEDERAL AVIATION AGENCY	117		117			
FEDERAL COMMUNICATIONS COMMISSION						
FEDERAL HOME LOAN BANK BOARD						
LIBRARY OF CONGRESS	33				33	
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	14,850	6,455	7,289	620	314	172
NATIONAL SCIENCE FOUNDATION	9,762	1,100	4,507	1,255	2,900	
OFFICE OF EMERGENCY PLANNING						
SMALL BUSINESS ADMINISTRATION						
TENNESSEE VALLEY AUTHORITY						
UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY						
VETERANS ADMINISTRATION	37	13		24		

Table D-9. *Federal intramural and extramural obligations for scientific and technical information, by agency and activity, fiscal year 1966 (estimated)*

[Thousands of dollars]

Agency and subdivision	Total	Intramural: Total intramural	Publication and distribution	Documentation, reference, and information services	Symposia and audio/visual media	R&D in information sciences, documentation and information systems, techniques and devices	Management and administration—information programs and services
TOTAL, ALL AGENCIES	258,673	181,804	49,974	90,230	15,869	7,378	18,353
Departments							
DEPARTMENT OF AGRICULTURE, TOTAL	13,156	13,133	2,269	8,749	1,601	161	353
Agricultural Research Service	1,828	1,825	749	269	781	...	26
Cooperative State Research Service	62	62	5	...	55	2	...
Economic Research Service	229	229	197	1	31	...	...
Farmer Cooperative Service	122	122	107	...	15	...	...
Forest Service	1,939	1,919	859	237	615	16	192
National Agricultural Library	8,868	8,868	343	8,242	7	142	134
Soil Conservation Service	94	94	...	...	94	...	...
Statistical Reporting Service	14	14	9	...	3	1	1
DEPARTMENT OF COMMERCE, TOTAL	41,090	39,383	20,945	12,624	705	1,105	4,004
Bureau of the Census	206	192	66	29	27	70	...
Bureau of Public Roads	500	280	57	143	20	60	...
Coast and Geodetic Survey	185	155	91	27	17	2	18
Maritime Administration	5	3	...	...	3	...	...
National Bureau of Standards	7,130	5,827	2,096	2,875	587	269	...
Office of Business Economics	100	100	100	...	...	...	...
Patent Office	32,360	32,325	18,400	9,320	20	651	3,934
Weather Bureau	604	501	135	230	31	53	52
DEPARTMENT OF DEFENSE, TOTAL	99,628	69,087	11,043	36,621	8,076	4,073	9,274
DEPARTMENT OF THE ARMY	54,819	39,828	5,924	21,032	5,543	859	6,470
DEPARTMENT OF THE NAVY	13,319	6,332	2,763	2,032	510	514	513
DEPARTMENT OF THE AIR FORCE	20,253	12,330	2,303	4,584	1,650	2,700	1,093
DEFENSE AGENCIES	11,237	10,597	53	8,973	373	...	1,198
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	31,208	17,890	2,775	9,334	2,648	513	2,620
Food and Drug Administration	2,340	1,450	100	1,160	75	45	70
Office of Education	739	301	64	70	...	145	22
Public Health Service	27,611	15,833	2,381	8,084	2,517	323	2,528
National Institutes of Health	(17,587)	(6,597)	(1,099)	(2,608)	(1,327)	(199)	(1,364)
National Library of Medicine	(5,484)	(4,787)	(120)	(3,945)	...	(50)	(672)
Saint Elizabeths Hospital	6	6	4	...	2	...	...
Social Security Administration	200	200	183	...	17	...	...
Vocational Rehabilitation Administration	217	5	...	...	5	...	...
Welfare Administration	95	95	43	20	32	...	...
DEPARTMENT OF THE INTERIOR, TOTAL	10,338	10,181	6,127	2,671	479	662	242
Bureau of Commercial Fisheries	1,107	1,086	625	460	...	...	1
Bureau of Mines	960	960	650	250	50	...	10
Bureau of Reclamation	347	335	52	210	19	8	46
Bureau of Sport Fisheries & Wildlife	492	463	225	70	150	18	...
Bureau of Outdoor Recreation	10	5	1	3	...	1	...
Department Library	582	582	...	572	...	10	...
Geological Survey	6,530	6,530	4,486	1,075	159	625	185
National Park Service	57	57	53	1	3	...	...
Office of Coal Research	25	12	9	...	3	...	...
Office of Saline Water	184	115	6	24	85	...	...
Office of Water Resources Research	44	36	20	6	10	...	...
DEPARTMENT OF LABOR, TOTAL	157	157	81	40	34	...	2
Bureau of Employment Security	50	50	14	...	34	...	2
Bureau of Labor Standards	13	13	13	...	...	...	...
Office of Manpower, Automation, and Training	80	80	40	40	...	...	...
Women's Bureau	14	14	14	...	...	...	...
DEPARTMENT OF STATE, TOTAL	246	111	...	80	3	...	28
Agency for International Development	197	62	...	34	...	...	28
Departmental funds	49	49	...	46	3	...	...
DEPARTMENT OF THE TREASURY, TOTAL	45	45	13	32	...	...	...
United States Coast Guard	45	45	13	32	...	...	...
Other Agencies							
ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS	36	36	24	10	2	...	...
ATOMIC ENERGY COMMISSION	5,474	2,954	1,668	850	60	154	222
FEDERAL AVIATION AGENCY	528	523	192	212	64	...	55
FEDERAL COMMUNICATIONS COMMISSION	13	13	3	5	5	...	...
FEDERAL HOME LOAN BANK BOARD	11	11	...	11	...	...	...
LIBRARY OF CONGRESS	12,485	12,252	...	12,004	7	241	...
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	26,870	9,050	3,953	3,350	1,500	44	203
NATIONAL SCIENCE FOUNDATION	14,100	3,723	134	2,652	...	200	737
OFFICE OF EMERGENCY PLANNING	3	3	...	3	...	...	...
SMALL BUSINESS ADMINISTRATION	25	25	25	...	...	...	...
SMITHSONIAN INSTITUTION	1,576	1,576	452	794	185	25	120
TENNESSEE VALLEY AUTHORITY	25	25	...	25	...	...	...
UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY	1,120	1,120	200	50	200	200	470
VETERANS ADMINISTRATION	539	506	70	113	300	...	23

TABLE D-9. *Federal intramural and extramural obligations for scientific and technical information, by agency and activity, fiscal year 1966 (estimated)*—Continued

[Thousands of dollars]

Agency and subdivision	Extramural					
	Total extramural	Publication and distribution	Documentation, reference, and information services	Symposia and audio/visual media	R&D in information sciences, documentation and information systems, techniques and devices	Management and administration—information programs and services
TOTAL, ALL AGENCIES	76,869	21,544	29,939	9,609	10,948	4,829
Departments						
DEPARTMENT OF AGRICULTURE, TOTAL	23		8		15	
Agricultural Research Service	3		3			
Cooperative State Research Service						
Economic Research Service						
Farmer Cooperative Service						
Forest Service	20		5		15	
National Agricultural Library						
Soil Conservation Service						
Statistical Reporting Service						
DEPARTMENT OF COMMERCE, TOTAL	1,707	1,211	195	48	253	
Bureau of the Census	14			14		
Bureau of Public Roads	220	70			150	
Coast and Geodetic Survey	30			30		
Maritime Administration	2			2		
National Bureau of Standards	1,303	1,138	145		20	
Office of Business Economics						
Patent Office	35			2	33	
Weather Bureau	103	3	50		50	
DEPARTMENT OF DEFENSE, TOTAL	30,541	8,760	11,156	3,538	2,468	4,619
DEPARTMENT OF THE ARMY	14,991	5,716	5,694	600	874	2,107
DEPARTMENT OF THE NAVY	6,987	2,294	1,704	927		2,062
DEPARTMENT OF THE AIR FORCE	7,923	620	3,343	1,966	1,544	450
DEFENSE AGENCIES	640	130	415	45	50	
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, TOTAL	13,318	1,858	4,780	3,668	2,999	13
Food and Drug Administration	890		890			
Office of Education	438	50	10	300	65	13
Public Health Service	11,778	1,776	3,790	3,278	2,934	
National Institutes of Health	(10,990)	(1,485)	(3,324)	(3,247)	(2,934)	
National Library of Medicine	(697)	(291)	(406)			
Saint Elizabeths Hospital						
Social Security Administration						
Vocational Rehabilitation Administration	212	32	90	90		
Welfare Administration						
DEPARTMENT OF THE INTERIOR, TOTAL	157	53	56	34	14	
Bureau of Commercial Fisheries	21	2		19		
Bureau of Mines						
Bureau of Reclamation	12		10	2		
Bureau of Sport Fisheries & Wildlife	29	16			13	
Bureau of Outdoor Recreation	5	1	3		1	
Department Library						
Geological Survey						
National Park Service						
Office of Coal Research	13	7	3	3		
Office of Saline Water	69	19	40	10		
Office of Water Resources Research	8	8				
DEPARTMENT OF LABOR, TOTAL						
Bureau of Employment Security						
Bureau of Labor Standards						
Office of Manpower, Automation, and Training						
Women's Bureau						
DEPARTMENT OF STATE, TOTAL	135		135			
Agency for International Development	135		135			
Departmental funds						
DEPARTMENT OF THE TREASURY, TOTAL						
United States Coast Guard						
Other Agencies						
ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS						
ATOMIC ENERGY COMMISSION	2,520	716	977	238	589	
FEDERAL AVIATION AGENCY	5		5			
FEDERAL COMMUNICATIONS COMMISSION						
FEDERAL HOME LOAN BANK BOARD						
LIBRARY OF CONGRESS	233				233	
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	17,820	7,750	8,750	746	377	197
NATIONAL SCIENCE FOUNDATION	10,377	1,190	3,877	1,310	4,000	
OFFICE OF EMERGENCY PLANNING						
SMALL BUSINESS ADMINISTRATION						
SMITHSONIAN INSTITUTION						
TENNESSEE VALLEY AUTHORITY						
UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY						
VETERANS ADMINISTRATION	33	6		27		

APPENDIX C

EXAMPLES OF UTILIZATION OF NASA TECHNOLOGY

Biotelemeter for Hospital Use

A large aerospace company has recently added a wireless cardiac monitoring system to their product line. This compact biotelemetry system was originally developed under NASA sponsorship to monitor life functions of astronauts during actual or simulated space flight without encumbering electrical leads or bulky amplifying and transmitting equipment. The system is now employed in hospital intensive care wards.

"Wheelchair" Without Wheels

This was a device originally designed by Space-General Corporation that would be landed on the moon and would walk on six legs about its surface collecting samples of soil, analyzing them, and telemetering the data back to earth. The device was seen by a NASA Technology Utilization Officer in California who got a pediatrician at the University of California in Los Angeles in touch with the designers at Space General. (Space General has already tested a prototype lunar walker and the pediatrician viewed a film showing it walking over rocks and steep grades.) The UCLA pediatrician was immediately intrigued with the idea that the lunar walker might well be adapted to the design of a new kind of wheel chair, permitting a paraplegic to cross terrain heretofore unmanageable with a wheeled vehicle.

UCLA obtained funding from the Children's Bureau of the Department of Health, Education and Welfare to construct a prototype walker based on the design of the lunar walker. The prototype has since been constructed and is now undergoing testing.

Air Bearing Support Table

An Alabama company is marketing an air bearing support table developed as a result of air bearing technology emanating from a NASA Center. One of its applications is in medical diagnosis where it permits more precision and reliability in measuring the magnitude of the recoil and impulse of the heart.

Device to Measure Heart Beat of Chick Embryo

The events leading to the conversion of the NASA cosmic dust detector into an instrument to measure the heart beat of a chick embryo began at the Ames Research Laboratory in Palo

Alto, California. Vernon Ragollo, an engineer, had just designed a device to count dust particles in outer space. It consisted of a large target attached to a small crystal possessing the property of generating a minute current of electricity when twisted. Thus, when cosmic dust or a micrometeoroid struck the large target, it would, in turn, twist the crystal slightly, generating a current of electricity. This would be amplified and recorded. Shortly thereafter, he happened to overhear a conversation between two biologists at lunch. One biologist was remarking that there was no convenient way to measure the heart beat of a chick embryo; that he had to break the shell and place electrodes into the tissue. Vernon thought about this for a moment and in his mind compared the forces imparted by micrometeoroids to what he imagined might be the forces created by a beating chick embryo's heart, and concluded that his instrument might well be sensitive enough to do the job. He told the biologists the principles of his device. A brief conversation had both scientists scurrying in opposite directions--the biologist to bring the egg and Vernon to convert his device. By the time the biologist had brought the egg, Vernon had removed the large target from the crystal and replaced it with a small egg basket. The egg was placed in the basket and the click of a dial brought a dancing blip across the oscilloscope screen tracing out a heart beat. The biologist was amazed. To further check the system, Vernon then placed the egg in an incubator because the heart beat increases as the temperature goes up. He tested the egg again and the blip on the screen danced faster.

It was at this point that the Technology Utilization Officer (TUO) at Ames heard about the interesting experiment bring conducted by the biologist and the engineer. Recognizing the potential value of the innovation, he prepared a flash sheet briefly describing the chick heart beat detector (or avian ballistrocardiograph) and sent the description to the Technology Utilization Division at NASA Headquarters at Washington, D. C. Here the information in the flash sheet was carefully evaluated and then disseminated to potentially interested people.

By coincidence, it was at just this time that concern over the consequences of thalidamide was high and the Food and Drug Administration was particularly interested in instruments that could help them measure drug-induced changes in developing embryos. A phone call was made from NASA Headquarters to scientists at the Food and Drug Administration. They expressed immediate interest. Following several more telephone calls and conferences, it was decided to send an FDA scientist skilled in working with chick embryos to the NASA Ames Research Laboratory to evaluate the instrument. Dr. Jaqueline Verrett, a pharmacologist, left for what started out to be a three-day visit. She became so enthustiastic about the potential of the innovation that she spent a total of two weeks measuring the effects of various drugs with the instrument. She later reported her findings at a meeting of the Federation of American Biologists.

Then another element necessary in the eventual widespread use of any innovation emerged: A manufacturing firm became interested. A west coast electronics firm learned of the device, further adapted it for sale, and now offers the instrument at a reasonable cost.

Differential Temperature Transducer

A small company in California, a manufacturer of temperature transducers and related readout equipment, is offering a compact transducer that provides an accurate, responsive, high signal-to-noise measurement of the in and out temperatures of flowing liquids in strong electric and magnetic fields. This instrument was developed at a NASA field center for use with an electric arc to solve the problem of obtaining accurate measurements of temperature rises in the presence of a strong magnetic field. Other suggested applications are in the fields of chemical processing, nuclear reactor technology, internal combustion engine testing, Klustron development and in specialized calorimetry.

Alkali Silicate Paint

A midwestern company is using the alkali silicate vehicle paint developed at Goddard Space Flight Center on the internal surface of their externally fired, steel calcining kettles. They first learned of this coating material through mailing of the Tech Brief (No. 64-10026). After requesting and receiving additional data, they produced a small quantity of the coating for testing. Tests included heating to 2400°F, heating to 2000°F in a corrosive atmosphere, soaking in concentrated sulfuric acid for one hour, and abrasive testing. After passing these severe tests, the coating was applied to the inside of the calcining kettles. After three months the coating showed no visible signs of wear or degradation in the corrosive, 600° to 800°F, abrasive environment. This performance represents an appreciable saving because failure of the previously used coating required the calcining process to be interrupted every three months to descale, clean, and recoat the kettles. In addition, the company reports improvement of the product quality, resulting from the elimination of impurities, i.e., from the previously used coating.

Device Turn-Off

A company produces a silicon controlled rectifier whose turn-off time is approximately 100 us. Document No. AD 430901 referred to several ways that the turn-off time of such silicon controlled rectifiers could be changed. As a result of the techniques described in this document, their device No. 5TCR was tested at turn-off times down to 50-60 us. This device is thus usable over a wider frequency range.

If they had decided to attempt such an experiment without benefit of the document, it would have taken approximately two months of research time by their engineers. With the information given in the document, however, their tests were completed in two days. This alone is worth perhaps $5,000 without considering the increased market potential of the 5TCR device.

Ultrasonic Leak Detection

A large manufacturing company was interested in finding a fast and economical means of detecting minute pin hole flaws in a welded product. A thorough search by experienced Regional Dissemination Center applications engineers provided this company with the necessary information from the NASA Lewis Center on ultrasonic leak detection techniques and subsequently put this firm in touch with several commercial organizations which produced such equipment. Timely experiments conducted by one of these firms in conjunction with the RDC client has offered promising preliminary results, which may result in the installation of a quality control system offering a superior product.

New Material

A company needed to locate a material capable of accommodating high density magnetic fields for use as a core material in a pen-drive mechanism.

The firm had developed a magnetically driven servo recorder with only one moving part. The pen, on a drive coil, slides along a one-inch diameter core piece in response to a variable magnetic field. They wanted to produce a model that would handle a larger chart by extending the length of the core piece without changing the diameter. In this way, no retooling would be necessary.

A retrospective search on high flux density materials was performed. This search identified a material that would satisfy the flux requirements but it cost over 70 times as much as the material currently in use. They were able to ascertain from the documents, however, that no low cost material existed that would operate at the desired flux densities. Thus they are able to proceed, without further research or experimentation, confident that retooling is necessary to produce the new, larger model. The resulting benefits to the company were: (1) an unnecessary R&D project was avoided, and (2) the company estimated savings in excess of two man-months.

Temperature Change Adjustment Circuit

A manufacturing firm in St. Louis, Missouri, was seeking an improved means of controlling the speed of a condenser fan motor in proportion to a change in temperature. The temperature sensitive circuit described in NASA Tech Brief 63-10537 appeared to be applicable and prompted a call to a NASA Regional Dissemination Center for suggestions on the type of temperature sensitive diodes to be used. A diode type was suggested and this circuit is now being employed by the company in the laboratory model of a temperature control system. It is indicated that the "multiple post pressure scanner" of Tech Brief 64-10031 will be implemented soon as a part of some in-house test equipment.

Metal to Metal Bonding

A manufacturer of computer tape reels was experiencing difficulty in meeting a delivery schedule with high quality reels. The major problem involved the attachment of aluminum reel flanges to a cast aluminum hub. Parts assembly by adhesive bonding was slow. There was an overflow of excess adhesive requiring removal from the tape channel. Assemblies were out of alignment tolerances.

The manufacturer contacted a Regional Dissemination Center and a search of NASA literature was made on adhesive bonding in an effort to find an adhesive which cured at room temperature and could be efficiently applied. NASA Documents N62-13131, Boron Reinforcements for Structural Composites; N62-16787, Research on Heater Tension Pads and High Temperature; N64-16272, Capability Development of Adhesive Bonded Studs; and IAA Document A64-19100, Which Adhesive for Bonded Metal Assembly?, identified specific adhesives suitable for the application and the sources of supply. Report N62-16787 was of particular value in this regard.

An applications engineer at the Center recommended several machining modifications to provide a groove in the periphery of the reel hub to act as a trap for excess adhesive to reduce the overflow. Latest reports from the company indicate that schedules are being met and that the assembly problem has been virtually eliminated.

Industrial Application of NASA Computer Program

As the result of receiving full flash sheet information on MFS-140, "Nth Order and Partial Differentiation of Algebraic and Transcendental Expressions by Digital Computer," (flash sheets generated by Marshall Space Flight Center) scientists in two different electronics firms contacted a Regional Dissemination Center concerning further information.

Each had reviewed the descriptive information sent to them and felt the program would fit certain of their particular computational problems.

A telephone contact with the Technology Utilization Officer at Marshall disclosed that a "Fortran" program deck was available and that it could be loaned to interested users. The program deck was mailed to those requesting it.

It is estimated that several man months would have been involved in writing and checking the computer program mentioned above.

Additionally, these two firms did not have to wait until they could internally develop the program. Thus significant savings in time and money were achieved.

Reduction of Welded Tubular Steel

The general manager of a small manufacturing company reported to one of the Regional Dissemination Centers that the RDC had helped the company to break a technical bottleneck in developing a low-cost method for reducing welded steel tubular hydraulic reservoirs.

The problem was to reduce 1/8" wall mild steel welded tubes of 5" diameter to 3" diameter for a length of 2½" at one end. This end is then threaded so that wall thickness must be maintained. Previous attempts were thwarted due to tearing and wrinkling of the tubing and as a result the company was unable to produce completed hydraulic Jack units because of the bottleneck.

The RDC personnel, using NASA reports, sketches and technical detail, were able to suggest changes in tooling and production of the much needed prototypes was begun within three days. The company is continuing to refine the process and is currently producing parts which were previously unavailable.

Random Function Tracer

A firm in Massachusetts is presently marketing a floating arm graphics recorder. It provides fast, accurate measuring and recording for cartography, photogrammetry, and oceanography, and is used to trace, digitize, and record coordinate data from maps, profiles, and other X-Y functions. Originally developed at a NASA center for use in connection with lunar mapping, a prototype was exhibited to another government service who contracted with the Massachusetts firm to produce this device.

Amplifier Circuit

A firm which specializes in the manufacture of precision wire-wound resistors and temperature controls, reported that they are presently using the amplifier circuit described in a NASA publication, "A Compact DC

Servo Power Amplifier," (F.S-AC-38) to increase the sensitivity of a standard panel mounted test instrument. "This amplifier allows us to use a more rugged instrument for production line use and still obtain the sensitivity required."

Engine Life Expectancy

The company was considering replacement of several reciprocating gas engine compressors with gas turbine type compressors. The main component of the gas turbine compressor is a standard jet aircraft engine widely used in civil and military aviation. The company desired information and data pertaining to the life expectancy of these gas turbines under conditions of static, continuous use.

After a search of NASA literature yielded no relevant results, RDC personnel contacted several of the specialized information sources available. Several persons at Wright-Patterson AFB were contacted who had been engaged in testing the type of jet engine in question for many years. Although they had no data relating to static continuous conditions, they did provide valuable information and an estimate of the minimum life.

The Technology Utilization Officer at Lewis Research Center was then contacted. A meeting was convened at the Lewis Research Center attended by representatives of NASA, the jet engine manufacturer, another firm, and RDC personnel. The purpose of the meeting was to discuss factors affecting the life of the engine and to try to arrive at a suitable life expectancy. NASA engineers thoroughly familiar with the engine were available as impartial consultants. The meeting resulted in much valuable information transferred and a consensus relative to life expectancy. The manufacturer agreed to collect and provide as much historical data as possible.

The company was able to establish a realistic life expectancy for the equipment in question for amortization and economic evaluation purposes. The meeting at Lewis also generated further interest in the subject of lubrication of the new equipment.

Solvent

Periodically, it is necessary for a company to remove lithography from cans of competitive products. They are then relabeled and used in consumer acceptance tests and taste-panel work. The removal had been accomplished

An Industrial Applications Report, Number NASA-255 (NASA Number N64-20321) described a paint remover which was "more efficient and more universally applicable" than the existing systems on the market. Many solvents and removers had been tried without success. They were provided complete information. After careful study, the company selected an efficient, alternate formulation which contained only immediately available chemicals.

The use of this innovation will save the company several thousand dollars annually.

It will eliminate a hazardous operation with regard to health.

In addition, it has potential applications in plant maintenance.

Welding of Thin Metal

A manufacturing company was using soldering for a particular thin metal (.004" to .006" thick) joining operation. They were interested in better techniques for doing this same job. A retrospective search identified the Tungsten-Inert-Gas (TIG) welding process. Since then other searches in this area have supplied them with valuable operating parameters for best performance of the equipment. They have at this time invested about $10,000 in two welding machines and after a period of further testing and training plan to purchase more equipment for introduction into their production operation.

This technique will eliminate several component parts now required in the assembly.

It will effect a significant man-hour saving on the assembly line.

It extends the usable temperature range of the manufactured part.

It provides an inhouse capability to manufacture component parts which were previously purchased.

Precision Casting Technique - Tech Brief 63-10008

A medium size firm in St. Louis, Missouri, manufactures butterfly valves used in breweries. As a direct result of reviewing information from NASA they modified the process used to manufacture the butterfly flapper in their lager valve.

Prior to adopting the process described in Tech Brief 63-10008, the part was made of one stamped piece and one machine-turned piece, welded together.

The company asked their supplier to make the part for them using the precision casting technique described in the Tech Brief for making wind tunnel models. The resulting part is smooth, is held to a tolerance of ±0.003 in., requires no cleaning and is a one piece casting. This change of manufacturing process has several cost saving advantages, including the complete elimination of several broaching operations that were previously required.

Soldering

A company in St. Paul, Minnesota, had a quantity production contract on a transistorized digital read-out device which they had designed and developed. In order to minimize unit rejects due to faulty electrical connections, and to insure a high quality of fabrication, it was necessary that they train and educate their assembly line workers on soldering technique. This need prompted their management personnel to use the handbook entitled, "Reliable Electrical Connections," from the NASA Marshall Space Flight Center as a standard training reference on soldered electrical connections. They feel that the detail description of techniques provided in this book <u>shortened the training time considerably</u>, and resulted in their reaching peak production much earlier than had been expected.

<u>Cold Galvanizing Air Bearing Pads</u>

A manufacturer of livestock equipment is using cold galvanizing on their steel livestock equipment. It is used on areas where the hot dip galvanizing has been burned by welding and also is used as additional protection for the remaining galvanized steel.

This same company is now in the process of designing air bearing pads and compatible floor surfaces for use in their warehouse operations.

This company learned of both of these innovations through NASA publications and follow-on efforts by staff members of one of the Regional Dissemination Centers.

Solution of Metal Porosity Problem

A large utility company, performing research on advanced power conversion techniques, had been plagued with a problem of metal porosity. A Regional Dissemination Center was able to supply information which, while developed by the NASA for a completely different purpose, solved the utility's problem. The chairman of the board stated that the potential value of this one transfer must be predicted to be in the multimillion dollar range, when the new energy system becomes commercially useful.

Line Following Servomechanism

A small firm in California, specializing in servo-instrumentation techniques, is marketing a function generator, a device that will automatically trace a line and provide output in digital form. This precision instrument was designed at a NASA center to overcome certain disadvantages usually found during tests requiring a high degree of resolution of accuracy. The NASA use was primarily to present a digital value of Mach numbers in the wind tunnels; however, industry use includes control systems for machine tools, fire control apparatus, and other applications requiring storage and handling of complex equations.

APPENDIX D

EXAMPLES OF UTILIZATION OF AEC-GENERATED TECHNOLOGY

Laminar Flow Clean Room

In 1960, the Atomic Energy Commission filed for a patent on a maninar flow clean room developed by Sandia Corporation. Since then, a new industry has come into being to meet the demand for laminar flow clean rooms, work stations, and portable units. About 30 manufacturers are active in supplying laminar-flow equipment, and thousands of clean work stations have been installed in industry and government facilities. Laminar flow clean rooms are applicable to such non-nuclear purposes as the fabrication of electronic components and as hospital operating rooms.

Memory Elements

Atomic Energy Commission developments for recovering uranium, thorium and vanadium from ore leach liquors have given impetus to commercial manufacture of suitable amines by several companies including Rohm and Haas, Union Carbide, Gulf, Archer-Daniels-Midland, General Mills, Armour and Eastman. Two companies, Union Carbide and

Virginia-Carolina, are producing di2-ethylhexylphosporic acid (D2EHPA). Most suppliers have now set up screening tests and customer service studies of their own reagents or are subcontracting such studies to private research centers.

Separation Chemistry Techniques

The AEC's solvent extraction research program produced new extractants and processes that have provided the basis for expanded use of the technique in separations chemistry in many facets of industry. The most useful and versatile extractants developed in the program have been amine compounds, organophosphorous compounds, and substituted phenols.

Refractory Metal Purification Techniques

Basic research requirements for pure material resulted in the development by AEC contractors of techniques for the purification of tungsten, tantalum, and columbium. These purification techniques are now being applied throughout the metals industry.

New Superconducting Alloy

The columbium-zirconium alloy, which is now being applied widely in applications of superconductors, was discovered in the course of an AEC-sponsored program. AEC-supported programs have clearly shown that the metallurgical variables of superconducting wires--such as prior working history, impurity content, and heat-treatment--have major effects on the superconducting properties of the wire. As a result of basic studies on the theory of alloying, it was found that precipitation heat treatment at about 800 $^{\circ}$C resulted in a tenfold increase in the critical current density of high-field superconductors, such as columbium-zirconium alloys. The increased current density is vital in the application of such superconductors for high field solenoids, thermonuclear plasma containment, spacing screening, friction-free guidance gyroscopes, and for loss free power transmission. Superconductors are being made, using these techniques, by Supercon and by the Union Carbide Stellite Corporation. Superconducting magnets employing such material are sold commercially by Magnion, Inc., and by Varian Associates.

Power Tube Seals

Research on large ceramic-to-metal seals needed for fusion devices has influenced the design and production of power tubes. RCA is now using such seals in the manufacture of power tubes.

High Current Switches

The need to switch currents in the multimillion ampere range in the controlled fusion program has brought about the development of fast, high current switches which are now used in plasma experiments for space, magnetohydrodynamics and other applications. The General Electric Company is now marketing an entire line of ignitron switch tubes based upon developments done for the controlled fusion program.

Contributions to Computer Technology

The store-program electronic digital computer has been entirely developed since World War II, and has, indeed, come into extensive use only in the last decade. At an early stage in the development of these machines, the AEC joined with the Office of Naval Research and the Office of the Chief of Ordnance, U. S. Army, in supporting the work of the late John von Neumann. Many of the basic ideas of machine organization in use by the computer industry today are due to the von Neumann group, working at the Institute for Advanced Study, Princeton, New Jersey. These ideas were embodied not only in the Princeton machine, but also in others built in AEC National Laboratories.

Two recent contributions to industrial applications are:

a. The Digital roster generators manufactured by the Computer Measurements Corporation were developed from an AEC design.

b. Fast digital logic circuits called Nanocards were developed by the AEC for use in counter experiments at high energy accelerators. Nanocards are now produced by several companies. They have found considerable usage in a variety of industries employing fast digital computers.

Cell Separation Capability

Interagency agreements have been reached between the Atomic Energy Commission and the National Institutes of Health (involving both the National Cancer Institute and the National Institute of Allergy and Infectious Diseases) to modify and adapt a zonal ultracentrifuge developed by the Atomic Energy Commission for the purpose of separating cells, viruses, and cell particles.

For several years, the Oak Ridge National Laboratories' Biology Division pursued the development of a high speed zonal ultracentrifuge as a basic research tool for the separation of cellular components as a part of the cell physiology project. Late in Fiscal Year 1962, it became apparent that it would be necessary to undertake a major design task on centrifuge drive and rotor systems to attain the high speeds required. The design work was cosponsored by the Atomic Energy Commission and the National Institutes of Health.

Industry and universities have been kept fully informed of the project continually throughout the effort. Among the media used to inform potential users of accomplishments in the program have been the following:

1. Publication of scientific papers in the journals dealing with such topics. 2. Publication of semiannual scientific reports on progress. 3. Sponsoring of information and demonstration meetings. 4. Dissemination of drawings of centrifuge systems. 5. A full-scale monograph is in process of preparation dealing with zonal liquid ultracentrifuge systems to date.

In addition to a potential major step forward in health research as a result of this program, considerable technology has been transferred to industry in terms of ability to machine to find dimensions, knowledge of metals and metal stress factors, skill and knowledge in the preparation of fine rotating parts, and skill in the calculation of critical stages in hazard from rapidly rotating cylinders and the behavior of liquids under high G forces.

Spinco Division, Beckman Instruments, Incorporated, is manufacturing the rotor for the currently approved and tested design of the centrifuge and now has more than 40 of these instruments sold or on order. International Equipment Company is preparing to manufacture and sell certain tested designs of the zonal liquid centrifuge.

In addition to 12 universities and two government agencies present at the last progress report meeting on the project, the following industrial companies were also represented: Electro-Nucleonics, Inc.; Abbott Laboratories; Parke Davis & Co.; Pittman-Moore Division, Dow Chemical Company; Spinco Division, Beckman Instruments, Inc.; International Equipment Co.; Squibb Institute; Mechanical Technology; Harshaw Chemical Co.; Lilly Research Laboratories; Dorr-Oliver, Inc.; W. R. Grace and Company; Merck Institute; General Electric Co.; Melpar, Inc.; Flow Laboratories; Trio-Tech, Inc.; C. Pfizer and Co.; and Proctor & Gamble.

APPENDIX E

Two Evaluations of Industrial Relevance

The authors requested two groups of people familiar with aerospace technology and industrial needs to rate the various broad categories of technology in terms of their relevance to the needs of industry.

The categories are those used by the NASA Scientific and Technical Information Division in its document announcement journal, Scientific and Technical Aerospace Abstracts.

The two groups performing the relevance rating function were: (1) Members of the ASTRA project team at Midwest Research Institute, Kansas City, Missouri. (2) Professional personnel associated with the Aerospace Research Applications Center (ARAC) at Indiana University, Bloomington, Indiana.

Both groups have had several years' experience in attempting to match available government-generated technology to the needs and objectives of industrial organizations in their geographical regions. Both organizations are regional dissemination centers for the NASA Technology Utilization Program.

Both groups used like approaches in performing the rating task. In each case, four evaluators worked independently to rate each category on a scale of 1 to 3. (1 equals low relevance to industrial requirements and 3 equals very high relevance.) The individual ratings of each group of four evaluators were then averaged to arrive at the ratings shown on the following pages.

Both groups of evaluators judged two major categories of aerospace technology to have extremely high relevance to the needs of civilian industry. The two categories: (1) Auxiliary system, which includes such technical areas as energy conversion methods, hydraulic, pneumatic, and electrical systems, and actuating devices. (2) Machine elements and processes, which include developments related to such fields as bearings, seals, pumps, lubrication, friction and wear, quality control, material fabricating techniques, and inspection methods.

Eight additional categories of technology were given a rating of 2 or above by both teams of evaluators. Those categories: (1) Biosciences. (2) Communications. (3) Electronic equipment. (4) Instrumentation and photography. (5) Metallic materials. (6) Nonmetallic materials. (7) Structural mechanics. (8) Thermodynamics and combustion.

Evaluation by Midwest Research Institute

BROAD TECHNICAL AREA	RELEVANCE RATING
Aerodynamics--includes aerodynamics of bodies, combinations, internal flow in ducts and turbomachinery; wings, rotors, and control surfaces.	1.0
Aircraft--includes fixed-wing airplanes, helicopters, gliders, balloons, ornithopters, etc.; and specific types of complete aircraft (e.g., ground effect machines, STOL, VTOL); flight tests; operating problems (e.g., sonic boom); safety and safety devices; economics; and stability and control.	1.0
Auxiliary Systems--includes fuel cells, energy conversion cells, and solar cells; auxiliary gas turbines; hydraulic, pneumatic and electrical systems; actuators; and inverters.	2.6
Biosciences--includes aerospace medicine, exobiology, radiation effects on biological systems; protective clothing and equipment; physiological and psychological factors.	2.0
Biotechnology--includes life support systems, human engineering, crew training and evaluation, and piloting.	1.7
Chemistry--includes chemical analysis and identification (e.g., spectroscopy).	1.7
Communications--includes communications equipment and techniques; noise; radio and communications equipment and techniques; noise; radio and communications blackout; modulation telemetry; tracking radar and optical observation; and wave propagation.	2.0
Computers--includes computer operation and programming; and data processing.	1.0

Electronic Equipment--includes electronic test equipment and maintainability; component parts, e.g., electron tubes, tunnel diodes, transistors; integrated circuitry; microminiaturization.	2.0
Electronics--includes circuit theory, and feedback and control theory.	1.3
Facilities, Research and Support--includes airports; lunar and planetary bases including associated vehicles, ground support systems; related logistics, simulators; test facilities (e.g., rocket engine test stands, shock tubes, and wind tunnels); test ranges; and tracking stations.	1.3
Fluid Mechanics--includes boundary-layer flow; compressible flow; gas dynamics; hydrodynamics; and turbulence.	1.0
Geophysics--includes aeronomy; upper and lower atmosphere studies; oceanography; cartography; and geodesy.	1.0
Instrumentation and Photography--includes design, installation, and testing of instrumentation systems; gyroscopes; measuring instruments and gages; recorders; transducers; aerial photography; and telescopes and cameras.	2.3
Machine Elements and Processes--includes bearings, seals, pumps, and other mechanical equipment; lubrication, friction, and wear; manufacturing processes and quality control, reliability; drafting; and materials fabrication, handling, and inspection.	3.0
Masers--includes applications of masers and lasers.	1.0

Materials, Metallic--includes cermets; corrosion; physical and mechanical properties of materials; metallurgy; and applications as structural materials.	2.3
Materials, Nonmetallic--includes corrosion; physical and mechanicsl properties of materials (e.g., plastics); and elastomers, hydraulic fluids, etc.	2.0
Mathematics--includes calculation methods and theory; and numerical analysis.	1.0
Meteorology--includes climatology; weather forecasting; and visibility studies.	1.0
Navigation--includes guidance; autopilots; star and planet tracking; inertial platforms; and air traffic control.	1.0
Nuclear Engineering--includes nuclear reactors and nuclear heat sources used for propulsion and auxiliary power.	1.0
Physics, General--includes acoustics, cryo genics, mechanics, and optics.	1.7
Physics, Atomic, Molecular, and Nuclear--includes atomic, molelecular and nuclear physics.	1.0
Physics, Plasma--includes magnetohydrodynamics.	1.0
Physics, Solid-State--includes semiconductor theory; and superconductivity.	1.0
Propellants--includes fuels; igniters; and oxidizers.	1.0
Propulsion Systems--includes air breathing, electric, liquid, solid, and magnetohydrodynamic propulsion.	1.0

Space Radiation--includes cosmic radiation; solar flares; solar radiation; and Van Allen radiation belts.	1.0
Space Sciences--includes astronomy and astrophysics; cosmology; lunar and planetary flight and exploration; and theoretical analysis of orbit and trajectory.	1.0
Space Vehicles--includes launch vehicles; manned space capsules; clustered and multistage rockets; satellites; sounding rockets and probes; and operating problems.	1.0
Structural Mechanics--includes structural element design and weight analysis; fatigue; thermal stress; impact phenomena; vibration; flutter; inflatable structures; and structural tests.	2.0
Thermodynamics and Combustion--includes ablation, cooling, heating, heat transfer, thermal balance, and other thermal effects; and combustion theory.	2.0
General--includes reports of a broad nature related to industrial applications and technology, and to basic research; defense aspects; law and related legal matters; and legislative hearings and documents.	1.3

Evaluation by ARAC (Indiana University)

Broad Technical Area	Rank Average*	Remarks
Aerodynamics	1.5	Very limited applicability for non-aerospace firms.
Aircraft	1.0	Very limited applicability for non-aerospace firms.
Auxiliary Systems	2.5	Excellent for fuel cells and physical control mechanisms.
Biosciences	2.0	Of most value to food and pharmaceutical firms.
Biotechnology	2.0	Of most value to food and pharmaceutical firms.
Chemistry	2.3	The general chemical analysis material is good.
Communications	2.0	Excellent for electrical engineering interests.
Computers	1.8	Excellent references.
Electronic Equipment	2.3	Good electrical engineering material.
Electronics	1.3	Often too theoretical for many industrial firms.
Facilities	1.8	An occasional listing of interest.
Fluid Mechanics	2.0	Many of these listings are highly theoretical.
Geophysics	1.3	Except for listings on air pollution, this section is of primary interest only to oil companies.
Instrumentation	2.0	Good electrical engineering information.
Machine Elements	2.7	Of high relevance to a broad cross-section of firms.
Masers	1.5	Interest limited and relatively specialized.
Materials, Metallic	2.5	Relatively high relevance to many firms.
Materials, Non-metallic	2.0	Information on plastics and ceramics is good.
Mathematics	1.7	Specialized and highly theoretical.
Meteorology	1.5	Very limited.

Broad Technical Area	Rank Average*	Remarks
Navigation	1.3	Extremely limited.
Nuclear Engineering	1.5	Very limited.
Physics, General	2.0	Useful for electrical firms and those interested in optics.
Physics, Atomic	1.7	Information on general testing of limited use.
Plysics, Plasma	1.5	Very limited interest.
Physics, Solid State	2.0	Good coverage on semiconductors; typically, not applications oriented.
Propellants	1.8	Of limited interest to non-aerospace firms.
Propulsion Systems	2.0	Good reference on non-exotic fuels and engines.
Space Radiation	1.0	Extremely limited.
Space Sciences	1.3	Extremely limited.
Space Vehicles	1.3	Extremely limited.
Structural Mechanics	2.8	Of high interest to a broad cross-section of firms.
Thermo & Combustion	2.0	Excellent references for non-exotic combustion.
General	1.5	Almost too general to be of interest.

*3=High
2=Medium
1=Low

APPENDIX F

An Evaluation of Relevance to Urban Problems

Many of the nation's more pressing social problems today center on urban life and the problems of living in a large metropolitan area.

While the solutions to most of these problems likely require heavier inputs in terms of social innovation than technological knowledge, there are seemingly areas of technical need to which already available technology might be applied.

One evaluation of the potential for application of aerospace technology to urban problems has been made by TEMPO, the advanced studies arm of the General Electric Company. (This study was supported in part by the Western Operations Office of NASA.)

The city problems identified by TEMPO as "most amenable to technological solutions" are those of:

- The urban physical environment, including air pollution, transportation, and waste disposal.
- Urban public health, including environmental health hazards and accident prevention.
- Community security.
- Urban social environment, including housing and urban renewal.

The study group also concluded that methodologies and analytical techniques, developed by agencies such as NASA, including systems analysis, operations research, and management planning, "can offer many contributions to solution of many city problems."

In addition, 32 broad categories of technology applicable to 25 critical problem areas were analyzed for potentiality of technological solutions. The results of that analysis appear on the following table. The analysis suggests that technology generated by the Defense Department, NASA, and AEC is potentially useful in a wide range of city problems--particularly in relation to transportation, waste disposal, air pollution, environmental health hazards, accidents and public safety, and police and fire protection.

PROBLEM CATEGORY \ TECHNOLOGY CATEGORY	1 AERODYNAMICS	2 AIRCRAFT	3 AUXILIARY SYSTEMS	4 BIOSCIENCES	5 BIOTECHNOLOGY	6 CHEMISTRY	7 COMMUNICATIONS	8 COMPUTERS	9 ELECTRONIC EQUIP. AND ELECTRONICS	10 FACILITIES, RESEARCH & SUPPORT	11 FLUID MECHANICS	12 GEOPHYSICS	13 INSTRUMENTATION AND PHOTOGRAPHY	14 MACHINE ELEMENTS & PROCESSES	15 MASERS AND LASERS	16 MATERIALS { METALLIC & NON-METALLIC	17 MATHEMATICS	18 METEOROLOGY	19 METHODOLOGIES & ANALYTICAL TECHNIQUES	20 NAVIGATION	21 NUCLEAR ENGINEERING	22 PHYSICS { GENERAL, ATOMIC MOLECULAR NUCLEAR	23 PHYSICS { PLASMA, SOLID-STATE	24 PROPELLANTS	25 PROPULSION SYSTEMS	26 SPACE RADIATION	27 SPACE SCIENCES	28 SPACE VEHICLES	29 STRUCTURAL MECHANICS	30 THERMODYNAMICS AND COMBUSTION	31 PUBLIC INFORMATION SERVICES	32 HUMAN FACTORS	POTENTIAL RANKING (1 TO 32)
(A) URBAN PHYSICAL ENVIRONMENT																																	
1. TRANSPORTATION	●	●	●			●	●	●	●		●			●	●	●	●		●	●		●	●	●	●		●	●		●	●	●	23
2. WATER SUPPLY AND POLLUTION			●	●	●	●		●	●	●	●	●	●			●	●		●		●	●				●	●		●		●		19
3. AIR POLLUTION	●		●	●	●	●	●	●	●		●	●	●	●		●	●	●	●		●	●	●	●	●	●	●	●		●	●	●	27
4. WASTE DISPOSAL		●	●	●	●	●		●	●	●	●	●	●	●		●	●	●	●		●	●				●	●	●			●	●	23
5. HOUSING FACILITIES AND SERVICES			●		●		●	●	●	●			●			●	●		●		●	●					●		●	●	●	●	17
																																TOTAL	109
(B) URBAN SOCIAL ENVIRONMENT																																	
1. JUVENILE DELIQUENCY		●	●				●	●	●	●						●			●									●			●	●	11
2. RACE AND DEPRIVATION			●				●	●	●	●						●	●		●								●				●	●	11
3. SLUMS AND URBAN RENEWAL			●		●	●	●	●	●	●						●	●		●		●	●					●		●		●	●	16
4. WELFARE AND UNEMPLOYMENT		●	●	●		●	●	●									●		●								●		●		●		11
5. EDUCATION AND SCHOOL SYSTEMS			●				●	●	●	●			●		●	●	●		●								●		●			●	13
																																TOTAL	62
(C) URBAN ECONOMIC ENVIRONMENT																																	
1. CITY ADMINISTRATION			●				●	●	●	●			●				●		●												●		9
2. BUSINESS AND INDUSTRY			●		●	●	●	●	●		●		●	●	●	●		●		●	●	●	●		●		●	●	●		●		21
3. FACILITIES OPERATION			●				●	●	●	●						●	●		●		●	●					●				●	●	13
4. LAND USE PATTERNS								●	●	●		●				●	●		●			●											8
5. URBAN PLANNING			●					●	●	●						●	●		●	●		●			●		●				●	●	13
																																TOTAL	64
(D) URBAN PUBLIC HEALTH																																	
1. ENVIRONMENTAL HEALTH HAZARD	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●		●	●		●	●	●	●	28
2. ACCIDENTS AND PUBLIC SAFETY	●	●	●		●	●	●	●	●		●	●	●		●	●	●	●	●			●	●	●		●	●	●		●	●	●	25
3. ILLNESSES AND INFECTIOUS DISEASES			●	●	●	●		●	●	●			●				●					●				●	●					●	13
4. HOSPITALS AND MEDICAL FACILITIES		●	●	●	●	●	●	●	●	●			●	●	●	●			●		●	●	●				●		●		●	●	21
5. PUBLIC HEALTH DEPARTMENTS					●			●	●								●		●							●					●		7
																																TOTAL	94
(E) URBAN SECURITY																																	
1. INDIVIDUAL SECURITY			●		●	●	●		●				●																			●	7
2. COMMUNITY SECURITY		●	●			●	●	●	●	●		●	●		●	●		●	●				●								●	●	17
3. COMMERCIAL SECURITY		●	●		●	●	●	●	●	●			●		●	●		●	●				●								●	●	17
4. RIOTS AND ORGANIZED CRIME			●			●	●	●	●			●	●		●			●	●	●			●	●					●		●	●	16
5. POLICE AND FIRE PROTECTION	●	●	●			●	●	●	●		●	●	●	●	●	●	●	●	●	●	●		●	●	●		●	●	●	●	●	●	27
																																TOTAL	83
POTENTIAL RANKING (1 TO 25)	5	9	23	7	13	16	19	24	24	16	8	9	16	7	10	19	18	9	22	6	10	14	9	6	5	7	17	7	11	6	21	19	

Figure 1. Evaluative matrix for relating the application of NASA technologies to city problems.

APPENDIX G

An Evaluation of Relevance to Missions of Federal Agencies

The responsibilities of a large--and increasing--number of federal agencies encompass the development of technological solutions to public problems.

In many cases, it seems reasonable that the results of research and development conducted by NASA, AEC, and the Defense Department would be, to some degree, applicable to the needs and objectives of the programs being carried out by these other federal agencies.

Some examples of interagency technology transfer already exist. Three immediately come to mind: (1) The design concept incorporated in the NASA lunar walker has been adapted to the development of a new kind of "wheel chair" that permits a paraplegic to traverse difficult terrain. (2) The principle of a micrometeoroid detector developed by NASA has been incorporated into a commercially available device to detect the heartbeat of chick embryos. (3) The zonal liquid centrifuge developed by the Atomic Energy Commission has considerable applicability in medical research programs.

The authors of this paper, with assistance from several well informed persons, have attempted to show in the following table some additional areas of potential interagency transfer of technology.

The authors selected several government agencies whose responsibilities embraced the seeking of solutions to problem areas where technological inputs would seem to be particularly valuable. The listing of agencies is not intended to be all-inclusive, but only representative. The authors then selected technological areas to which the Defense Department, Atomic Energy Commission, and National Aeronautics and Space Administration have made (or continue to make) significant contributions. Then the authors, with assistance, have attempted to match agency needs to technological advances. The results of this matching appear in the following table.

The technical areas listed should not be interpreted as being the only areas that might contribute to the missions of the agencies mentioned. Nor should it be inferred that the technologies listed will assuredly contribute to the missions of the agencies. This listing was developed solely on the basis of informed judgment but the areas listed appear to have considerable potential for contribution to the missions of the agencies in question.

Agency and Indication of Ongoing Responsibilities	Potentially Relevant Technologies*
The National Institute of Allergy and Infectious Diseases	
Fosters research on the causes, prevention, diagnosis, and treatment of infectious and allergic diseases. Also conducts basic research on the growth requirements, metabolism, and conditions of survival of micro-organisms, including physiology, biochemistry, biophysics, chemotherapy, and immunology.	Micromanipulator devices Environmental control Precision Measurement Bioelectrochemistry Centrifuge technology Infrared radiometry X-ray technology Chromatography Extraterrestrial life detection Lasers

* Technological areas that seem to have particular relevance to the needs and objectives of the programs of each agency. Technologies chosen are those to which NASA, AEC, and DOD have made significant contributions.

The National Institute of Dental Research

Conducts research into the causes, prevention, diagnosis, and treatment of dental diseases and conditions. Specifically, in the broad area of dental caries, perilodental diseases, various oral systematic relationships, and abnormalities of growth and development affecting the oral cavity, face, and head.	Microelectronics Stress measurement Biocompatible materials Ultrasonic machining Anesthitization Microminiaturization Lasers

The National Cancer Institute

Fosters research into the cause, prevention, diagnosis, and treatment of cancer.	Infrared radiometry Lasers Hyperbaric Oxygenation Cellular Separation Techniques Cryogenics Thermographic Techniques

The National Institute of Mental Health

Fosters research into etiology and diagnoses treatment in prevention of mental diseases. Assists states in developing and maintaining adequate mental health facilities and programs.	Teaching aids Psychological studies Speech synthesis

The National Institute of Neurological Diseases and Blindness

Conducts research relating to the causes, prevention, diagnosis, and treatment of neurological and sensory disorders.	Cryogenics Micromanipulators Lasers Visual perception studies Biotelemetry Computer programming Sensing techniques

The National Institute of Arthritis and Metabolic Diseases

Conducts research on the causes, prevention, diagnosis, and treatment of arthritis, rheumatism, and metabolic diseases. Specific fields include the rheumatic diseases, metabolism, hematology, endocrinology, nutrition, biochemistry, radio biology, pathology, chemotherapy, toxicology, pharmacology, and endoepidemiology.	Fluid dynamics Radiation studies Lasers Nutrition studies Dialyzers

The National Heart Institute

Conducts research on the causes, prevention, diagnosis, and treatment of cardiovascular disease. Also on the nature of the aging process, and provides instruction on methods of diagnosis and treatment.	Pressure measurement Fluid dynamics Fluid interaction devices Silicones Biotelemetry Transducers and sensing devices Valve technology Hyperbaric oxygenation Weightlessness effects

The National Institute of General Medical Sciences

Fosters research in basic biomedical sciences, environmental health, and in certain communicable areas.	Sterilization techniques Environmental control Extraterrestrial life detection Socioeconomic studies Biotelemetry Life support systems

Bureau of Educational Research and Development (HEW)

Responsible for the identification of major problems in education, the collation and dissemination of information about education, the support of educational research, and assistance to the profession and the public in solving educational problems. Conducts research and experimentation in the development and evaluation of projects involving television, radio, motion pictures, and related media of communication.

Human factors engineering
Adaptive control systems
Photography
Telemetry
Automatic language translation
Teaching devices

Vocational Rehabilitation Administration (HEW)

Responsible for research to advance knowledge of ways of overcoming handicapping conditions.

Devices to extend human physical capabilities
Human factors engineering
Simulators
High strength-to-weight ratio materials
Transducers and sensing devices
Fastening devices and joining techniques

Food and Drug Administration

Some areas of research include the development of physical and chemical methods to determine freedom from adulteration of food; research on bacteriological and microanalytical methods for detecting filth and decomposition in food and drugs; new

Sterilization techniques
Extraterrestrial life detection
Radiation detection methods
Microanalytical chemistry

methods of testing antibiotics; development of methods of analysis of cosmetic preparations; analysis and certification of color additives; studies relative to potential radiation contamination of foods.	Food synthesis Waste management

Office of Manpower Automation and Training (Department of Labor)

Plans and directs developmental and experimental studies in all areas of manpower and automation to find solutions to problems which significantly affect the nation's ability to eliminate persistent and other types of unemployment and under-employment, and to evaluate the impact of and benefits and problems created by automation and other forms of technological programs.	Socioeconomic studies Training techniques Applied mathematics

Bureau of Labor Statistics (Department of Labor)

Some areas of research activity include programs of long-run economic growth with special reference to employment; research on causes of industrial accidents; research on general factors affecting manpower and production; applied research on revision of the consumer price index.	Computer programming Human factors engineering Accident prevention

Area Redevelopment Agency (Department of Commerce)

Development of industrial or commercial facilities, technical assistance, and economic development information, as well as direct assistance to state and local agencies concerned with and engaged in economic development activities.	All new technologies that can create new products and new industries.

Appalachian Regional Commission

Support of economic development programs which will contribute to the growth of the region. Programs include construction of a development highway system; construction and operation of multi-county health centers; application of land treatment and erosion control measures; support of timber development organizations; reclamation of land damaged by past mining practices; operation of a comprehensive water resources survey; construction of vocational education facilities; and sewage treatment facilities.	Materials Bioengineering Water management Waste management

United States Coast and Geodetic Survey
(Environmental Sciences Services Administration)

Research and development in oceanography, geomagnetism, seismology, gravity, geodesy, photogrammetry, and chartography.	Corrosion control Photogrammetry Telemetry Pumping systems Geomagnetic research Gravitational studies Sensing and detection devices Photography

Maritime Administration

Conducts research and development designed to provide progressive leadership in maritime technology in the areas of ship operations, ship construction, components, and techniques. Included in applied research and development program are studies of cargo handling; development and utilization of new ship designs; marine transportation systems; advanced compression concepts; and ship management techniques.	Fluid mechanics Corrosion control Containerization Material handling techniques Applied mathematics Computer-aided design PERT and other managerial techniques

Bureau of Public Roads	
Conducts research and development in areas including materials for highway use, highway design, signing and traffic control devices, human factors in traffic problems, highway planning, and the economic impact of highways.	Human factors engineering Computer-aided design Materials Coatings Advanced control techniques Corrosion prevention Signal systems
National Bureau of Standards/Institute for Materials Research	
Assists and stimulates industry in the development of new and improved products by supplying increased understanding of the basic properties and behavior of materials, and making available reliable qualitative information on the performance of materials.	Materials testing techniques Results of tests of materials, including data on such properties as toxicity, fatigue, impact resistance, chemical corrosion resistance, etc. Information on composite materials
National Bureau of Standards/Institute for Applied Technology	
Provides for the creation of appropriate opportunities for the use and application of technology within the Federal Government and within the civilian sector of American industry.	Wide range of applied research and engineering activity areas.

Agricultural Research Service
(Department of Agriculture)

Conducts basic and applied research in areas including application of engineering to agricultural production; livestock and poultry diseases; efficient methods of feed utilization, nutrition, improving resistance to diseases in extreme temperatures; control of insects, water-shed engineering, soil management, water management. Also diagnosis of disease-producing agents; testing biological products for potency, safety and purity; development of processing methods to destroy parasites and control food spoilage organisms.

Nutrition research
Extraterrestrial life studies
Ecological studies
Water management
Sensing devices and transducers
Analytical chemistry
Sanitation research

Agency for International Development (AID)

Assists other nations to improve their economic health.

Fabrication techniques
Socioeconomic studies
Wide range of other technical inputs

Office of Saline Water (Department of Interior)

Conducts research relative to development and improvement of conversion processes.

Corrosion control
Coatings
Materials
Fluid mechanics
Pump and valve technology
Heat transfer

Bureau of Commercial Fisheries
(Department of Interior)

Research for the purpose of assuring maximum yield of commercial fishery.

Materials
Pneumatics and hydraulics

resources. Areas of work include studies in biology, ecology, diseases and predators. Also technological studies on the composition and value of various fishes; development and improvement of methods of handling, processing, and storage; designing, testing, and improvement of fishing gear.

Ultrasonics
Material handling
Bearings, seals, and pumps
Lubrication and corrosion

Bureau of Mines (Department of Interior)

Research and development in mining, metallurgy, minerals, coal, petroleum, natural gas, and helium as well as health and safety in the mineral industries.

Environmental control
Explosives
Gas dynamics

Geological Survey (Department of Interior)

Performs surveys and investigations in topography, geology, and mineral and water resources. Also develops techniques, concepts, and instrumentation for prospecting and mapping.

Cartography
Geodesy
Geomagnetism
Photography
Sensors and transducers

United States Coast Guard (United States Treasury)

Responsibilities include development and testing programs for search and rescue aids, improvement of ship structures, and navigational techniques.

Telemetry
Fluid mechanics
Navigation and guidance

Bureau of Engraving and Printing (United States Treasury)

Performs research relative to printing processes.

Composite materials
Quality control
Metal forming
Feedback control

National Capital Transit Agency	
Responsibility to prepare a transit development program for the District.	Systems analysis Thermal insulation Traffic control PERT and other management techniques Applied mathematics Adaptive control
Urban Renewal Administration	
Responsibility includes programs for the prevention and elimination of slums, blight, and deterioration.	Systems analysis Socioeconomic studies Sensing and detection techniques Behavioral testing
Small Business Administration	
Provides assistance to improve the competitive strength of small businesses.	Wide range of technical areas
Arms Control and Disarmament Agency	
Conducts research and development to ensure that the technical processes and instruments are developed that would be necessary to ensure effective arms control and disarmament. Also concerned with conversion of defense facilities to productive uses.	Sensing and detection techniques Systems analysis Bioinstrumentation Radiation research

Veterans Administration

Research and development activities in both basic and applied medical research fall within the areas of all life sciences. Emphasis is placed on these diseases and disabilities of high incidence among veterans and on problems of aging.

Human factors engineering
Devices to extend human physical capabilities
Telemetry
High strength-to-weight ratio materials
Fastening devices and joining techniques
Micromachining
Microminiaturization
Sensing devices
Visual display techniques

APPENDIX H

Chronology of Federal Government Actions Involving the Diffusion of Science and Technology 1787-1950

1787	Constitutional Convention
1790	First Patent Law
	First Census
1800	Library of Congress
1802	Army Corps of Engineers
	United States Military Academy, West Point, New York
1803	Lewis and Clark Expedition
1807	Coast Survey Act
1816	Columbian Institute
1818	Discontinuance of the Coast Survey
	Army Medical Department
1819	Long Expedition to the Rockies
1824	Survey Act and increased activity of the Corps of Topographical Engineers
1825	John Quincy Adams's first annual message
1830	Authorization of work on weights and measures
	Navy Depot of Charts and Instruments
1832	Reestablishment of the Coast Survey
1836	Reorganization of the Patent Office
1838	United States Exploring Expedition
1839	First use of Patent Office fund for agricultural studies
1840	National Institute for the Promotion of Science
1842	Act in support of Morse's telegraph
	United States Botanic Garden
	Naval Observatory
	Fremont's first expedition to the Rockies
1845	United States Naval Academy
1846	Mexican War: Emory's reconnaissance from Fort Leavenworth to San Diego
	Smithsonian Institution
1847	David Dale Owen's and others' geological surveys of federally owned lands
	Lynch's Dead Sea Expedition

1848	United States and Mexican Boundary Survey
	American Association for the Advancement of Science
1849	Grant to Charles G. Page for electric locomotive
	Nautical Almanac Office
	Gilliss's U.S. Naval Astronomical Expedition to Chile
1851	Herndon and Gibbon's explorations of the valley of the Amazon
	Bache's presidential address before the AAAS
1852	Kane's expedition to the Arctic
	Perry's Japan expedition
1853	Pacific railroad surveys
	Ringgold and Rodgers's U.S. North Pacific Exploring Expedition
1859	President Buchanan vetoes land-grant college bill
1861	Government Printing Office
	Outbreak of the Civil War
1862	Act creating the Department of Agriculture
	Homestead Act
	Morrill Act for land-grant colleges
1863	Navy Permanent Commission
	National Academy of Sciences
	Army Signal Corps
1866	Navy Hydrographic Office separated from Naval Observatory
	Disbanding of the Corps of Topographical Engineers
1867	Clarence King's Geological Survey of the Fortieth Parallel
	Army Medical Museum
1868	Army Medical Library
1869	Lt. G. M. Wheeler's Geographical Surveys West of the Hundredth Meridian
1870	Meteorological work begins in Army Signal Corps
	J. W. Powell's Geographical and Topographical Survey of the Colorado River of the West
1871	Fish Commission
1873	F. V. Hayden's Geological and Geographical Survey of the Territories
1879	U.S. Geological Survey
	National Board of Health
1880	Bureau of American Ethnology, Smithsonian Institution

1881	Founding of the magazine SCIENCE
1884	Bureau of Animal Industry, Department of Agriculture
	Allison Commission
1886	Division of Economic Ornithology and Mammalogy, Department of Agriculture, forerunner of Biological Survey
1887	Hygienic Laboratory, Marine Hospital Service
	Hatch Act for Agricultural Experiment Stations
1888	Powell's irrigation survey
	Office of Experiment Stations, Department of Agriculture
1889	Elevation of Head of Department of Agriculture to cabinet rank
1890	Act transferring meteorological service from the Army and creating Weather Bureau, Department of Agriculture
1891	Astrophysical Observatory, Smithsonian Institution
1893	Army Medical School
1896	National Academy Committee on Forestry
1901	Bureau of Chemistry, Department of Agriculture
	Bureau of Plant Industry, Department of Agriculture
	Bureau of Soils, Department of Agriculture
	National Bureau of Standards
1902	Newlands Act and establishment of Reclamation Service
	Reorganization of Marine Hospital and Public Health Service
	Bureau of the Census
1903	Philippine Bureau of Science
	Committee on Organization of Scientific Work
1905	Transfer of forest reserves from Department of Interior to Department of Agriculture; change of Division of Forestry to Forest Service
1906	Pure Food and Drug Act
1908	Conference of governors on conservation
1910	Bureau of Mines
1912	Public Health Service
1914	Smith-Lever Act authorizing extension work, Department of Agriculture
1915	National Advisory Committee for Aeronautics
	Naval Consulting Board

1916	National Park Service
	National Research Council
1922	Bureau of Agricultural Economics, Department of Agriculture
1923	Naval Research Laboratory
	Bureau of Home Economics, Department of Agriculture
1926	National Research Fund
	Aeronautics Branch established in Commerce Department
1927	Radio Division of Department of Commerce
1930	National Institute of Health
1933	Science Advisory Board
	Tennessee Valley Authority
1934	Agricultural Research Center
1935	Bankhead-Jones Act for Agricultural Research
	National Resources Committee
	Soil Conservation Service
1937	National Cancer Institute
1938	<u>Research - A National Resource</u>
	Agricultural Adjustment Act
1940	National Defense Research Committee
1941	Office of Scientific Research and Development
	Entry into World War II
1942	Agricultural Research Administration
1946	Atomic Energy Commission
	Office of Naval Research
1950	National Science Foundation

APPENDIX I

Brief Reviews of Technical Information Programs of Selected Federal Agencies

A large number of federal agencies, offices, and bureaus that conduct, foster, and/or support research and development programs have technical information activities.

This Appendix gives brief descriptions of the technical information programs of a random sampling of such agencies. It is possible that, due to an interest in brevity, the descriptions here do not fully define or describe the total informational activities of the organizations represented. The purpose of this Appendix is simply to alert the National Commission on Technology, Automation, and Economic Progress to the fact that an extremely large amount of scientific and technical information is available, in one form or another, to support an effort to channel new technologies in promising directions.

U.S. Coast Guard

The Coast Guard conducts research, testing, and development associated with all phases of Coast Guard activities: civil engineering; electronic engineering. Information on this research is reported in testing and development division reports (approximately 40 annually), civil engineering reports (approximately 60 in existence to date), electronic engineering station project reports (approximately 40 issued annually). Existence of these reports is announced in bimonthly Engineers Digest, The Technical Abstract Bulletin and in the Monthly Catalog of Government Publications. The Office of Engineering of the Coast Guard distributes approximately 1,000 copies of the above listed reports to individuals, universities, and various industries in the maritime business, upon their specific request. However, all of the above listed publications are also available from the Superintendent of Documents. Therefore, the Coast Guard is not able to give an exact figure as to the volume of distribution of their reports.

The Coast Guard serves as secretariat for the Interagency Ship Structures Committee. Presently, about 170 reports have been published by this committee. Reports are sent to a mailing list of individuals, universities and industrial concerns, the total mailing list numbering about 400. Requests outside the mailing list are honored but rarely come from someone outside of "the professionals."

The Coast Guard publishes the Annual Report of the International Ice Observation and Ice Patrol Service in the North Atlantic. The Coast Guard distributes this report to about 800 non-profit organizations in all nations participating in the International Conference on the Safety of Life at Sea.

The Floating Units Division of the Coast Guard gathers data on weather, oceanographic and communications data as a service for other government agencies. The data is analyzed and published by the cognizant agency.

The Coast Guard is a member of the Interagency Committee on Oceanography which currently has approximately 18 publications available. The distributing agency for these reports within the United States Government is the Navy Department.

Bureau of Customs

The scientific activities of the bureau are centered on furnishing technical information to customs officers covering the analysis, sampling, weighing, and gauging of imported and exported merchandise. As a general rule, methods of analysis used by the Bureau of Customs are not published. Technical information is not widely distributed because it contains a large amount of proprietary industrial information. However, there are a few publications available: 42 circular letters have been published; 177 United States Customs Laboratory Methods Manuals have been published. Publications available can be obtained on written request if it is determined by the Bureau of Customs that the requestor should have the information in question. The existence of the Bureau of Customs publications is not announced in any of the standard government announcement bulletins.

Unites States Geological Survey

The Geological Survey conducts research in geology, water resources, conservation, and topography. Results of the Survey's work are published as (a) books and (b) maps and charts. Book publications can be divided into the following categories: bulletins, which are published at the rate of 100 annually; water supply papers, which are published at the rate of about 100 annually; professional papers, which are published at an annual rate of 100; circulars, which are published at an annual rate of about 15. Book publications are announced in the monthly New Publications of the Geological Survey which is mailed to a list of 12,000. All book publications are announced as available from the Superintendent of Documents. The Survey retains only a few copies for distribution to individual requests. In addition, the Survey purchases from the Superintendent of Documents 500 copies of any publication to mail to those libraries throughout the world which participate in the library exchange program of the Survey. Those 500 libraries are located throughout the world and in principle have a copy of each technical publication of the Survey. These copies are available for microfilming by potential users. Maps and charts prepared and printed by the Survey are available for purchase from the Survey, one of its field offices or from one of the Survey's authorized map agents (commercial). Maps are sold in an annual volume of approximately 6,600,000. Certain unpublished data (Parex. Stream Flow, Ground Levels) is available upon request from the Survey's headquarters office. Such data is usually published annually. Inquiries of a general nature are also answered on an individual basis by one of the 7 field offices of the Survey which have public inquiry offices.

Bureau of Mines

The bureau conducts research in the following areas: safety conditions in mines; metallurgy; mining; nonmetalic minerals; fuels technology; explosive technology; and helium. The bureau publishes the results of its research in the following types of publications:

1. Bulletins - which come out at the rate of about 10 annually, over 600 titles now being available in the series. New reports are disseminated by the bureau to a selected mailing list. The size of the mailing list varies with the particular bulletin in question but it usually is around 300 or 400 names. Individual copies may be purchased from the Superinentdent of Documents. No data is available on the number of copies of bulletins distributed annually because the bureau has no control on the number of documents distributed by the Superintendent of Documents.

2. Reports of Investigations - (This type of report covers a smaller field of technical inquiry than bulletins.) They are published at a rate of 200 annually. The bureau distributes copies to a selected mailing list of interested parties, the mailing list usually runs into about 300 names. Individuals are able to purchase copies of these reports from the Superintendent of Documents.

3. Information Circulars - (These circulars contain much marketing and economic data.) They are published at a rate of about 200 per year. Circulars are distributed to a selected mailing list of individuals number ing around 200. Individual requests are sent to the Superintendent of Documents. In addition to the above list of reports, various handbooks and pamphlets are available from the Bureau of Mines. Mineral industry surveys are prepared and are mailed to a selected list of industry specialists. This list numbers about 200. Bureau personnel publish about 500 to 600 papers a year in various journals and other professional publications. Bureau publications are announced by means of a Monthly List of New Publications which is mailed to those on the Bureau's mailing lists.

Office of Coal Research

The Office of Coal Research conducts a program of research and development designed to increase the value of the coal industry to the nation's economy by better and more efficient methods of mining, preparation and utilization of coal. All of this office's research and development work is done under contract.

Fifteen scientific and technical reports have been published so far as a result of research and development work supported by this office. (This office was established in 1960.)

These reports are distributed in one of three ways: by the Federal Clearinghouse from mailing lists of approximately 600 individuals, universities and industrial concerns, the mailing lists having been supplied to the Clearinghouse by the Office of Coal Research; by the Office of Coal Research through a specialized mailing list of individuals, universities and industrial concerns. These mailing lists are directed to those groups who might be interested in a particular publication. The Office of Coal Research also distributes copies of their reports in response to individual requests; companies working under contract to this office are urged to make distribution of reports on their contract R&D work to others in the coal business.

Federal Communications Commission

The FCC conducts a limited research, development and testing program related directly to the field of telecommunications and its obligations to serve as a regulatory body in that area.

Technical publications of the FCC include: research reports - these reports are on technical communications subjects and are produced at an annual rate of 10 a year; technical information bulletins are catalogs of acceptable communications equipment which are updated periodically. All publications may be obtained by writing directly to the FCC, Office of the Chief Engineer.

Federal Aviation Agency

The FAA conducts research in the fields of aviation medical service, air traffic control, weather, and aircraft safety. Presently, the FAA is also reporting specialized R&D efforts in connection with the development of a supersonic transport.

Reports resulting from R&D supported by the FAA include: Research and Development Progress Report which is an annual publication available from the Superintendent of Documents; Technical Reports which are published at an annual rate of about 250.

All of FAA unclassified material is disseminated to the scientific community through the Federal Clearinghouse. In addition, NASA and DOD (DDC) receive a copy of each technical report published by FAA (classified and unclassified) for their scientific and technical information retrieval systems. Technical reports on the development of the supersonic transport are handled by NASA and the DDC.

Bureau of Reclamation

This bureau conducts research in the following areas: chemical engineering; concrete; conservation of plant control; hydraulics; soil mechanics and foundation engineering; and geology.

The bureau publishes many documents containing technical information, but the most widely used reports are Engineering Monographs and Technical Reports.

1. Engineering Monographs are now disseminated from Washington at the rate of about 15,000 copies per year. There are 34 different monographs now available for distribution.

2. Technical Reports are distributed for the bureau by its Denver Research Center. There are approximately 200 reports available covering about 6 categories of research. The volume of annual distribution is close to 25,000 documents.

Publications are distributed upon request to those individuals, scientists, engineers, universities, and industrial labs on the mailing list of the bureau to receive technical documents. The mailing list for Engineering Monographs is maintained in Washington and numbers about 12,000.

Office of Saline Water

The Office of Saline Water carries out its research and development program relative to the improvement of existing conversion processes and the development of ideas and data for new processes. The results of this office's research and development efforts are published in various media. Technical reports were being published at the rate of 7 per year in 1961 but 100 were published in 1964. The office now has available one consolidated published bibliography of material available on saline water research. This is available upon request to the Superintendent of Documents. The Office of Saline Water Research also makes available proceedings and papers of various symposia and conferences on saline water upon receipt of an individual request.

By far, the greatest number of documents distributed are the technical reports. Until early this year, the office distributed some of its publications, the bulk being distributed by the Federal Clearinghouse in Springfield, Virginia. Now, however, publications are distributed by the Superintendent of Documents upon request to that office. Any inquiries received by the Office of Saline Water for their consolidated bibliography or for technical reports are referred to the Superintendent of Documents.

Defense Documentation Center

One of the larger handlers of scientific and technical information, the Defense Documentation Center (DDC) services the information needs to the entire defense community.

Documents flow into DDC at a rate in excess of 200 per day. For example, the agency processed 5040 documents in May of 1965, 4200 in June, and 4530 in July.

On the output side, DDC services document requests at a daily rate in excess of 5500. For example, in April, the facility processed 125,000 requests; in June, 137,000; in July, 119,000. In the twelve months ending April, 1965, it processed

1,200,000 requests for documents (vs. 953,000 in the preceding twelve-month period). During calendar 1965, the agency expects to handle 1.7 million document requests.

(The totals include requests for unclassified and unlimited documents, which are passed along to the Clearinghouse for Federal Scientific and Technical Information, which services those requests under inter-departmental agreement.)

In addition, DDC prepares bibliographies for qualified requestors.

As of Jan. 1, 1965, there were 3700 military organizations, 300 other Federal agencies, and 2000 industrial and educational concerns registered for DDC services.

Twice a month, the center publishes its announcement journal, Technical Abstracts Bulletin (TAB) and the TAB Index. Cumulated indexes are also provided.

Documents are microfilmed.

Local accessability to the document collection is provided through regionally deployed field services which have facilities for search, on-the-spot review, and print-outs of selected pages.

The Defense Documentation Center had its origin in July, 1945 when literally tons of captured German and Japanese technical documents were added to the mass of domestic R&D reports generated by World War II and the Army Air Force established an Air Documents Research Center. With the separation of the Air Force from the Army, the Air Force and the Navy combined to form the Central Air Documents Office (CADO). Two years later, the Army agreed to participate in CADO.

On May 14, 1951, Secretary of Defense George C. Marshall established the Armed Services Technical Information Agency (ASTIA), to serve all three military departments and their contractors. CADO and the Navy Research Section of the Library of Congress were incorporated to form ASTIA. ASTIA started with a collection of some 400,000 titles and received requests for 40,000 documents the first year. ASTIA continued until March 19, 1963 when the Agency was reconstituted as DDC. At that time ASTIA had a collection of nearly 700,000 titles and its annual requests for documents totaled more than a million. After 18 years of Air Force operational control, the functions performed by DDC were transferred to the Defense Supply Agency in November, 1963. The DDC collection, which now totals nearly 750,000 reports, spans the scientific spectrum from Astronomy to Zoology.

APPENDIX J

SCHOOL CONSTRUCTION SYSTEMS DEVELOPMENT PROJECT -- A REPRINT

SPL REPORTS

SCSD—A SIGNIFICANT CONCEPT

The School Construction Systems Development project was conceived to find answers to crucial problems in the construction of school buildings. The stated objective of the project is to provide architects and school districts with an *integrated system of construction components* which will

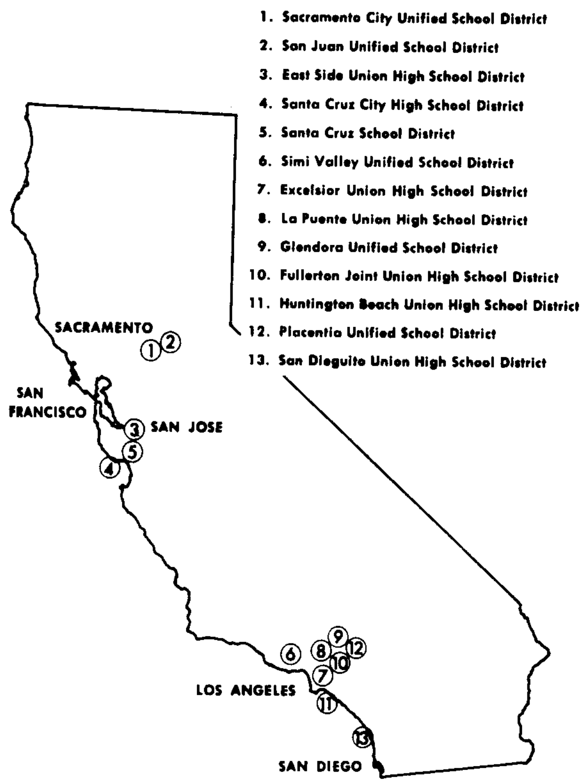
(1) offer architects desired design flexibility in meeting the changing program needs of individual schools,
(2) reduce the cost of school construction and give better value for the school building dollar in terms of function, environment, first cost and maintenance, and
(3) reduce the time needed to build a school.

The project has now progressed through its beginning stages and is rapidly approaching the target date for construction of a mock-up building of about 4,000 square feet to test the component system which will be used to build twenty-two schools by the end of 1967.

SCSD is a joint project of the School Planning Laboratory and the Department of Architecture of the University of California at Berkeley under a grant to Stanford University from Educational Facilities Laboratories, Inc., a non-profit corporation established by the Ford Foundation.

The project began on the premise that the pattern of building one school at a time does not provide sufficient opportunity or incentive for architects and manufacturers to explore approaches to building schools which depart significantly from traditional methods. Logically, a large contract for buildings was needed. To accomplish this, SCSD convinced thirteen school districts to pool their projected building needs and to offer the twenty-two buildings involved as an assured market for products to be developed by manufacturers.

The next step was an equally unusual one. SCSD architects and educators wrote a set of *performance specifications* for the building components required. These specifications were based on a comprehensive survey of building needs common to the school districts involved, with an emphasis on flexibility, which permits changes in the school program. Final specifi-



Locations of SCSD member districts

cations required development of a total system of four compatible components:

1. Structure
2. Lighting-ceiling
3. Heating, ventilating, and cooling
4. Interior partitions
   - fixed walls
   - demountable walls
   - panel-type operable walls
   - accordion-type operable walls

The objective in requiring a *total system* of compatible components was to eliminate any needless duplication of function while providing a high degree of flexibility. Over one hundred manufacturers expressed initial interest in the development of products, twenty-six finally submitted bids. Five of these

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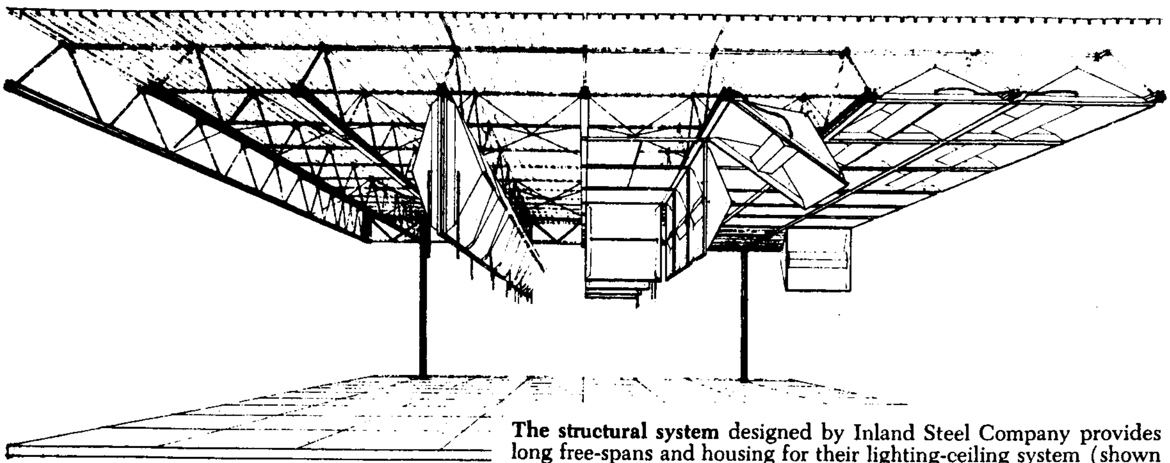


The structural system designed by Inland Steel Company provides long free-spans and housing for their lighting-ceiling system (shown in various stages of installation), air-conditioning and utility lines.

SCSD—*continued*

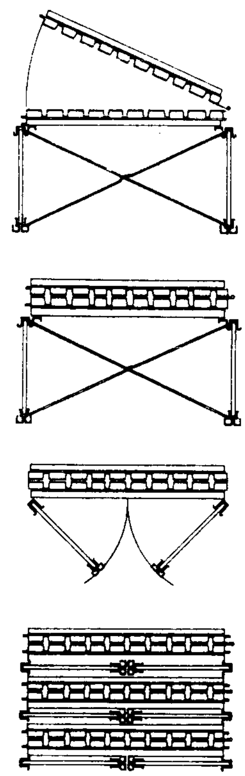
twenty-six have been selected to provide products for the buildings to be constructed. The specifications, as the results of the bidding show, are quite realistic and economically feasible even though they surpass any other known building system for total flexibility and function. In fact, in addition to satisfying all the SCSD specifications, the components of the five successful bidders will cost less than their conventional counterparts (figured on the basis of average building costs in California).

A basic premise of SCSD, from the very first, has been to avoid stock-plan or mass-produced schools. In order to avoid these pitfalls, the system does not include the exterior walls of a school building. Also, the SCSD components are considered architecturally neutral—neither dictating nor inhibiting design. Since the architect can put them together with the ease of an oversized "erector set" and still be certain that they are architecturally sound, he is free to concentrate on basic planning tasks such as space requirements and relationships.

THE COMPONENTS

Inland Steel Company was the successful bidder for both structural and lighting-ceiling system. Their products feature a maximum utilization of materials, resulting in minimum weight, while completely satisfying SCSD specifications. Inland's structural system is designed for easy shipment—no small item when long spans of roof trusses are involved – and easy erection on the job. The "loft-type" structural system serves as roof or floor, support for the lighting-ceiling system and housing for the heating, cooling, and ventilating ducts and utility lines. The system is built on a five-foot structural module and provides spans from 30 to 110 feet. (Fifty per cent of the building spans will be 55 to 70 ft.)

The lighting-ceiling system provides low-brightness lighting designed to maintain seventy footcandles and will be available in at least nine variations to meet specific needs. It includes considerations for controlling heat from lighting and can be given sound-absorbing qualities. The air-conditioning system by Lennox Industries of Marshalltown, Iowa, consists of roof-top units, each designed to provide air conditioning for a basic module of 3,600 square feet of floor space. The system is highly flexible, however, and it is possible to control independently the air conditioning for *any 450* square feet of a basic module.



Shipment and erection are made more economical by Inland Steel's ingenious technique of folding the structural system into a compact package.

—continued

SCSD—*continued*

Thus, a high degree of ventilating flexibility is assured to serve rooms of different sizes. The lighting-ceiling system provides outlets for the air-conditioning through a system of snap-in ducts and flexible hoses.

The SCSD specifications for fixed walls were satisfied along with those for demountable walls in a single bid by the E. F. Hauserman Company of Cleveland, Ohio. The result is that *all* walls in the schools to be built will be either demountable or operable types —thus providing *total* flexibility for all interior partitions. The Hauserman wall consists of a steel frame system and wall panels made of gypsum board sandwiched between preprimed sheetmetal. With this system, an entire wall, including doorways, can be moved with a minimum of effort.

The panel-type operable wall contract was awarded to Western Sky Industries of Hayward, California. Their wall comes complete with its own frame to enable the easy relocation of the entire unit. The design contains a simple mechanical expansion device to seal the door acoustically at the top and bottom. Each panel wall also includes a swing-type three-foot-wide pass door equipped with a conventional latch set.

The accordian operable wall is manufactured by the Hough Manufacturing Company of Janesville, Wisconsin. It is one of their standard products which has been improved to meet SCSD requirements. Like the panel-type wall, it comes complete with its own frame system to make easy relocation feasible.

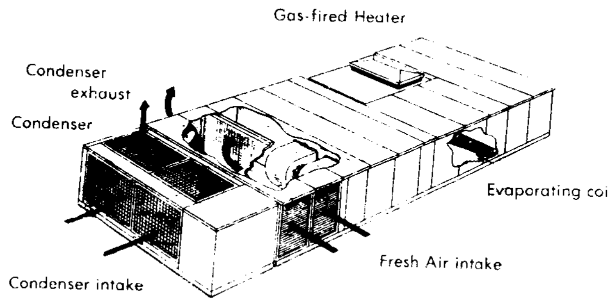
The SCSD demountable partitions by the Hauserman Company features a steel frame and pre-primed sheet metal covered panels which "snap" into place.

NEXT STEP

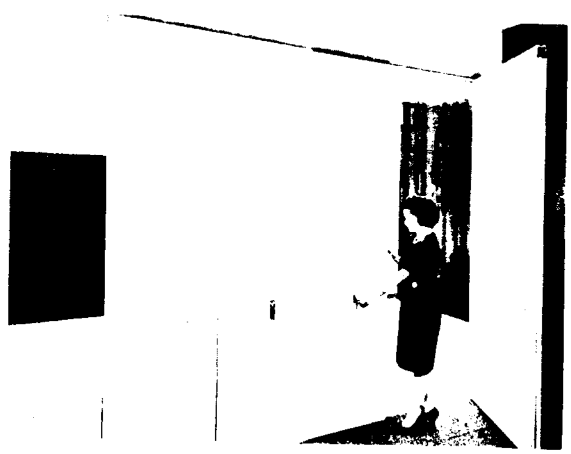
The SCSD timetable calls for construction to begin on a prototype building in May of this year. The building, to be located at Stanford University, will bring all the SCSD components together and provide a place for final field testing of ideas by manufacturers and architects. By June 1965, the testing stages will be completed and the manufacturers will begin to supply components to school sites. The construction of the twenty-two schools will proceed until the end of 1967.

The architects and educators on the SCSD project are confident that a major breakthrough in school construction has been realized.

Additional benefits from the project will likely include new marketable products for the building industry from the research and development done by all the companies who submitted bids. For the SCSD member school districts, the component concept will provide high-quality building performance and flexibility at a cost below that for conventional construction.



SCSD air conditioning roof-top units by Lennox Industries will serve independent areas as small as 450 square feet.



Panel-type operable walls by Western Sky Industries will include a three-foot passage door (shown open) and a frame system which permits easy relocation of the entire unit.

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